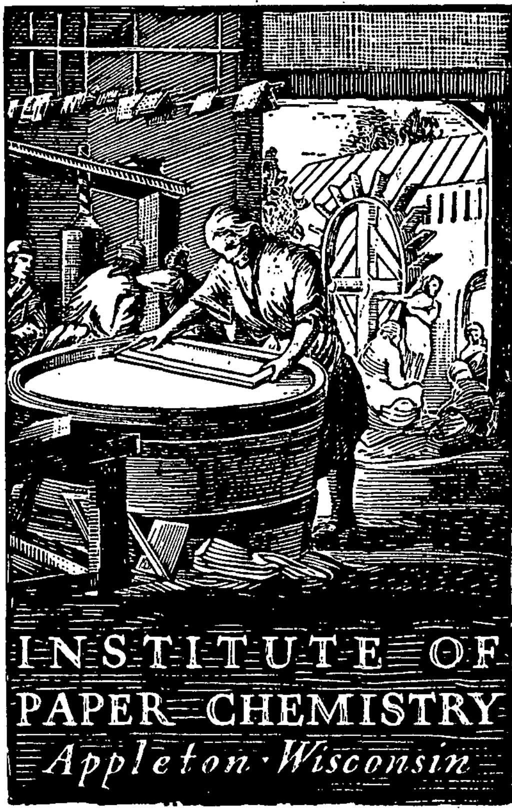

IMPROVED WEIGHT FACTORS FOR FIBER ANALYSIS

Project 3033

Report Two

A Progress Report

to

MEMBERS OF GROUP PROJECT 3033

November 20, 1972

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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Crown Zellerbach Corporation

P. H. Glatfelter Company

Great Northern Paper Company

Hammermill Paper Company

Kimberly-Clark Corporation

The Mead Corporation

Scott Paper Company

St. Regis Paper Company

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

IMPROVED WEIGHT FACTORS FOR FIBER ANALYSIS

SUMMARY

Weight factor determinations in this current investigation were made on: (a) submitted authentic pulp samples which had been prepared from both several species of southern yellow pine and several species of oak and (b) pulps prepared from acquired wood samples of these species and pulped at The Institute of Paper Chemistry.

Weight factor was found to be strongly influenced by the degree of cooking. The weight factors of pulps prepared from juvenile and mature wood of loblolly and slash pine with screened yields of approximately 45% and a 40 Kappa number level were, on the average, 15% lower than similar pulps having screened yields of approximately 52% and a 90 Kappa number level and 25% lower than pulps with screened yields of approximately 54% and a 115 Kappa number level.

Slash and loblolly pine pulps, prepared from juvenile wood with lower average densities and % screened yields than mature wood, also had slightly lower weight factor values than pulps prepared from the mature wood.

The limited data available would indicate that pulps prepared from species of slash pine have approximately the same weight factor value as similar pulps prepared from species of loblolly pine. The suggested weight factor of 1.55 (TAPPI Standard T 401 m-60) is an appropriate value for most pulps prepared from these wood species.

The weight factors obtained for pulps prepared from hardwood species of white oak were the same as those obtained for similar pulps prepared from species

of red oak. The factors obtained for all pulps prepared from these wood species were, in every instance, lower than the TAPPI suggested factor of 0.60. The results of this investigation would indicate that a weight factor of 0.45 or 0.50 would be more appropriate for pulps prepared from oak species.

Site and geographic location have an effect on wood density. No conclusions could be drawn from the pulp samples and limited data available, however, as to the extent these factors have on the weight factors of pulps prepared from species of southern yellow pine. The weight factor data available for species of oak would indicate that geographic location is not significant and has little effect on the ultimate weight factor values of pulp samples prepared from these particular wood species.

Plans for the program during the next six months include completion of weight factor determinations on northern and western softwood pulp samples and also on pulps prepared from other species of hardwood. Consideration will also be given to the development of a set of relative weight factors for hardwood species based on "vessel counts."

INTRODUCTION

The weight factors of pulps show marked variation between species of wood and also between pulps of the same species but from different geographic locations. The factors are affected to a lesser extent by the type and degree of cook, beating, and bleaching.

An accurate quantitative fiber analysis of a paper, board, or pulp sample makes it desirable to have available as complete a set of weight factors as possible which will cover the various pulps which may be encountered during the analysis of a sample furnish.

Project 3033, "Improved Weight Factors For Fiber Analysis," was initiated to investigate the weight factors of pulps prepared from wood species of most interest to the participating companies.

The first progress report of Project 3033 included the results obtained for weight factor determinations made on most of the softwood and hardwood chemical pulps which had been submitted by members of the project. The weight factors of one pulp (slash pine-unbleached kraft) from the TAPPI Fibrary and one grass (Esparto) pulp were also included in Progress Report One. A few of the wood pulp samples submitted at the initiation of this study, which supposedly contained but one species, were highly contaminated with other species. No determinations were made on these pulps.

Many authentic pulp samples have been submitted for investigation by cooperators of the project since the completion of Progress Report One. Important information as to the wood species being investigated, its geographic origin, density, class (i.e., juvenile or mature wood), cooking conditions, yield, Kappa number, etc., was also included for some of these pulps. Wood samples with known geographic locations have also been obtained for many of the species in which the members of the project have expressed interest. These pulps were chipped and pulped under controlled conditions at The Institute of Paper Chemistry for additional weight factor determinations.

The report that follows includes weight factor determinations made on pulps, received and prepared, of various species of southern yellow pine and oak.

EXPERIMENTAL METHODS AND MATERIALS

METHODS

The methods employed in making the weight factor determinations were the same as outlined in Progress Report One and were as follows.

A fifty-fifty mixture by weight of a standard pulp (i.e., cotton linters — J. H. Munktells Swedish Filtering Paper for Chromatography) with a known relative weight factor of 1.1 and the pulp under investigation are thoroughly mixed in a large Erlenmeyer flask. This fiber suspension is poured into six test tubes and each is diluted to the desired consistency (i.e., approximately 0.05%). Standard slides are prepared (a one-inch square field at each end of every slide) from each of the six pulp mixtures and the fibers mounted and differentially stained with Graff "C" stain (refer to TAPPI Standard T 401 m-60). The fibers are counted at a magnification of 100 diameters with the aid of a binocular microscope equipped with a mechanical stage and an eyepiece with a pointer. The fiber field is moved horizontally and all the fibers counted as they pass under the end of the pointer. The one square inch field is scanned five times on lines 4-mm. apart for a total count which usually totals between 200-300 fibers. Both sides of the six slides are determined in this manner for each determination. Since the weight factor for the standard pulp is known, the relative weight factor for the pulp being examined is readily calculated.

SAMPLES

The present study limits itself to the investigation of the weight factors of pulps prepared from several species of southern yellow pine and oak.

The pulps and pertinent information relating to them are presented in Tables I and II. The cooking conditions which were available for some of the above listed pulps are given in Tables III and IV.

TABLE I

PULPS SUBMITTED BY THE COOPERATING COMPANIES

Pulp No.	Cooperating Company	Wood Species and Class	Origin	Cook	Av. Wood Density, lb./cu.ft.	Total Yield, %	Screened Yield, %	Kappa No.
1	Great Northern	Slash-Mature	Ga., Fla., Ala.	Kraft (No. 1225A)	28.66	46.39	46.13	37.3
2	Great Northern	Slash-Juvenile	Ga., Fla., Ala.	Kraft (No. 1225B)	26.82	45.04	44.85	38.5
3	Great Northern	Slash-Mature	Ga., Fla., Ala.	Kraft (No. 1223B)	28.66	47.40	47.20	42.9
4	Great Northern	Slash-Mature	Ga., Fla., Ala.	Kraft (No. 1221B)	28.66	46.05	45.72	38.7
5	Great Northern	Loblolly-Juvenile	Ga., Ala.	Kraft (No. 1221A)	26.11	45.45	44.89	38.8
6	Great Northern	Loblolly-Mature	Ga., Ala.	Kraft (No. 1230A)	28.71	46.66	46.38	40.8
7	Great Northern	Slash-Mature	Ga., Fla., Ala.	Kraft (No. 1228A)	28.66	54.70	53.84	95.1
8	Great Northern	Slash-Juvenile	Ga., Fla., Ala.	Kraft (No. 1228B)	26.82	52.86	52.00	90.6
9	Great Northern	Loblolly-Mature	Ga., Ala.	Kraft (No. 1232A)	28.71	53.05	52.05	90.7
10	Great Northern	Loblolly-Juvenile	Ga., Ala.	Kraft (No. 1232B)	26.11	51.79	51.07	93.2
11	Great Northern	Slash-Mature	Ga., Ala., Fla.	Kraft (No. 1236A)	28.66	56.76	54.82	114.9
12	Great Northern	Loblolly-Juvenile	Ga., Ala.	Kraft (No. 1236B)	26.11	56.36	54.90	115
13	Great Northern	Slash-Juvenile	Ga., Fla., Ala.	Kraft (No. 1238B)	26.82	55.99	53.61	115
14	Great Northern	Loblolly-Mature	Ga., Ala.	Kraft (No. 1241B)	28.71	56.24	55.13	115.4
15	Riegel	Slash Pine (No. 503)	Miss.	Kraft (No. 14)	--	--	--	37.7
16	Riegel	Loblolly Pine (No. 502)	Miss.	Kraft (No. 15)	--	--	--	37.7
17	Riegel	Northern red oak No. 611 (Trees 60-90 yr. old)	N. Portmouth, N. H.	Kraft (No. 82)	--	--	--	10.8
18	Riegel	White oak No. 928 (3 trees approx. 25, 25 and 20 yr. old)	Woodworth, La.	Kraft (No. 158)	--	--	--	12
19	Hammermill	White Oak	Penn.	(CEH Bleach Soda)	--	--	--	14
20	Hammermill	Red Oak	Penn.	(CEH Bleach Kraft)	--	--	--	15
21	Hammermill	Water Oak	Ala.	(CEDED Bleach)	--	--	--	13

TABLE II

KRAFT PULPS PREPARED FROM ACQUIRED WOOD SAMPLES
AND PULPED AT THE INSTITUTE OF PAPER CHEMISTRY

Pulp No.	Wood Species	Origin	Tree Age, yr.	Height, ft.	D.B.H., in.	Total Yield, %	Kappa No.
22	Loblolly pine (3033-11)	Ga.	20-22	--	4.5-7	43.6	19
23	Loblolly pine (3033-9)	La.	19	50.0	7.2	46.0	18
24	Slash pine (3033-10)	Ala.	33	43.0	7.8	42.1	22
25	White oak (3033-24)	Wis.	80+	53.0	8.2	44.8	9
26	White oak (3033-19)	Va.	50	58.5	7.0	45.1	>9
27	Bur oak (3033-13)	Central Wis.	43+	46.4	7.2	48.1	>9
28	Post oak (3033-15)	Ala.	30	52.0	7.5	45.3	16
29	Southern red oak (3033-20)	Va.	--	51.5	7.3	47.9	>9
30	Southern red oak (3033-14)	Ala.	33	47.0	7.6	49.2	>9
31	Northern red oak (3033-6)	Northern Wis.	35	57.0	7.4	50.2	>9

TABLE III

COOKING CONDITIONS
GREAT NORTHERN PULPS

Liquor-to-wood ratio	4:1
Weight of chips	20 o.d. lb. (10 lb./side of split basket)
Active alkali	18% (40 Kappa number level
	15% (90 and 115 Kappa number level)
Sulfidity	30%
Cooking temperature	177°C. maximum
Time to top temperature	1 hour
Total cooking time	2 hours (40 Kappa number level)
	1 hr. 38 min. (90 Kappa number level)
	1 hr. 23 min. (115 Kappa number level)

TABLE IV

COOKING CONDITIONS
THE INSTITUTE OF PAPER CHEMISTRY PULPS

Digester charge, g. o.d.	50
Liquor-to-wood ratio	6:1
Active alkali as Na_2O, %	20
Sulfidity, %	25
Time to max. temp., min.	90
Time at max. temp., min.	75
Max. temp., °C.	175

DESCRIPTION OF WOOD SPECIES AND RESULTS OF WEIGHT FACTOR DETERMINATIONS

A brief description of the general characteristics, gross and microscopic features (1, 2) of the wood species of southern yellow pine and oak were given in Progress Report One and, for convenience, are included in the following section. The description of each species is followed by the results of weight factor determinations made on the current pulps under investigation. Included also are the weight factors reported previously in Report One for submitted southern yellow pine and oak pulp samples and any factors which had been determined previously (Institute Project 1499), before the initiation of Project 3033.

SPECIES OF SOUTHERN YELLOW PINE

General Description and Minute Anatomy of Wood Species

The wood contained in species of southern yellow pine (slash, loblolly, shortleaf, pitch, pond, Virginia, etc.) is moderately heavy to heavy (av. sp. gr. 0.45-0.56 green, 0.52-0.66 ovendry). The growth rings in the species are distinct, delineated by pronounced bands of thick-walled latewood fibers. The transition from earlywood to latewood is very abrupt and the widths of each vary within limits. The earlywood zone varies from very wide (slash pine, loblolly pine) to narrow (slow-growth shortleaf pine, etc.) while the latewood zone ranges from broad to narrow, varying greatly in width and density depending upon the age of the tree, conditions of growth and, within general limits, according to species. The rays are very fine and not visible (cross section) to the naked eye, except where they include a transverse resin canal, forming a fine, close, inconspicuous fleck on the quarter surface. Parenchyma are not visible. Both longitudinal (av. 90-150 µm. in diameter) and transverse (usually less than 70 µm. in diameter) resin canals with thin-walled epithelium are present. Canals in the heartwood are frequently occluded with tylosoids. The tracheids are up to 60 (av. 34-45) micrometers in diameter. The average length of the tracheids of longleaf, shortleaf, and slash pine is 4.5-5 mm. while that of loblolly is 3.5-4.0 mm., pond 3.0 mm. and Virginia 2.0-2.5 mm. The rays are of two types, uniseriate and fusiform. The uniseriate rays are numerous and 1 to 8+ cells high. The fusiform rays are scattered, with a horizontal resin canal 2-4-seriate in the central portion, tapering to a uniseriate margin up to 12+ cells high. Ray tracheids are present in both types of rays and are marginal and interspersed. The ray parenchyma are thin walled. The volume occupied by the rays averages approximately 8.4%.

The yellow or hard pines of southeastern and eastern United States cannot be separated on the basis of wood structure.

Photomicrographs of transverse surface areas prepared from wood samples of species of slash and loblolly pine are illustrated in Fig. 1, 2, and 3. The photomicrographs illustrate the extreme difference in cell wall thickness and wood density between early and latewood tracheids which is characteristic of species of southern yellow pine. Figure 1 illustrates the very abrupt transition from earlywood to latewood. The latewood zone in this particular annual growth increment is narrow but it may be broad, varying in width and density according to age of the tree, conditions of growth, and, within general limits, according to species.

Weight Factor Determinations

The results of weight factor determinations which have been made to date on pulp samples prepared from species of southern yellow pine are listed in Table V.

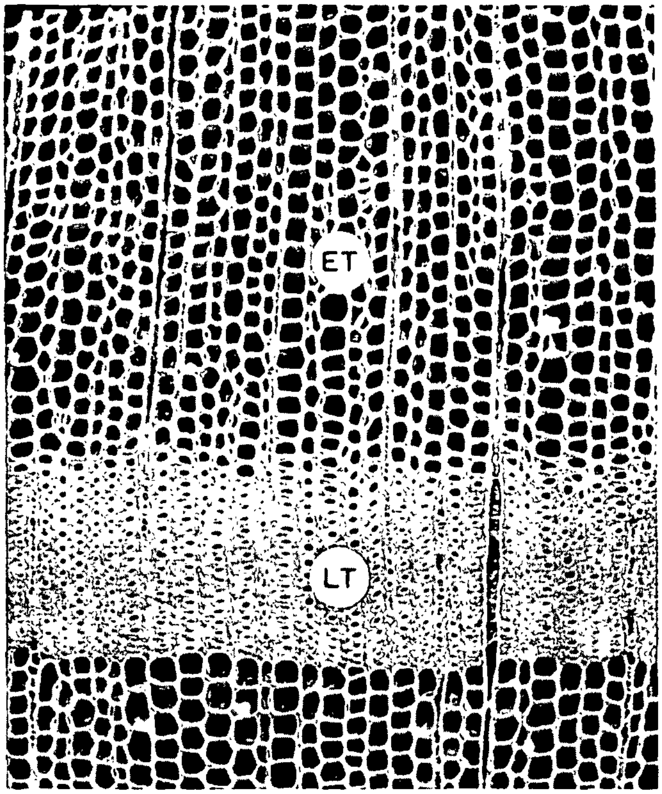

Figure 1. Photomicrograph (SEM) of Transverse Surface of Slash Pine, Ala. (IPC Sample — 3033-10). Latewood Tracheids (LT), Earlywood Tracheids (ET). Magnification — 100 Diameters

The data for Pulp Samples No. 20 through No. 23 were reported previously (Project 3033 — Progress Report One). Weight factor determinations for Pulp Samples No. 24 through No. 27 were made (IPC Project 1499) by Institute personnel before the initiation of Project 3033.

Except for a few pulp samples, the determined weight factors agree quite favorably with the suggested factor of 1.55 listed for species of southern pine kraft pulps in TAPPI Standard T 401 m-60. The determined factors for one or two of the pulps prepared from juvenile wood and also a bleached kraft pulp were 20-25% lower, while the factors for two or three samples prepared from mature wood and species of slash pine were 20-25% higher than the suggested standard.

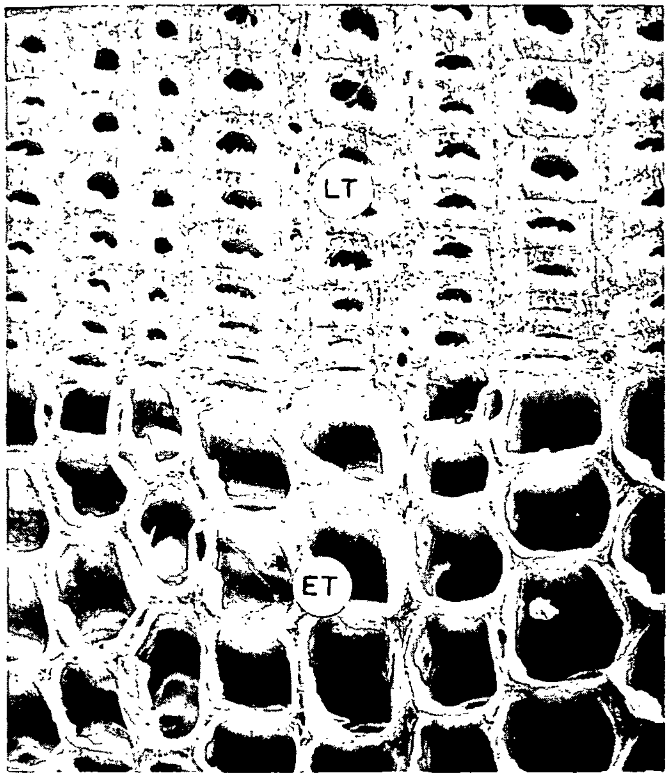

Figure 2. Photomicrograph (SEM) of Transverse Surface of Loblolly Pine, Ga. (IPC — 3033-11). Latewood Tracheids (LT), Earlywood Tracheids (ET). Magnification — 400 Diameters

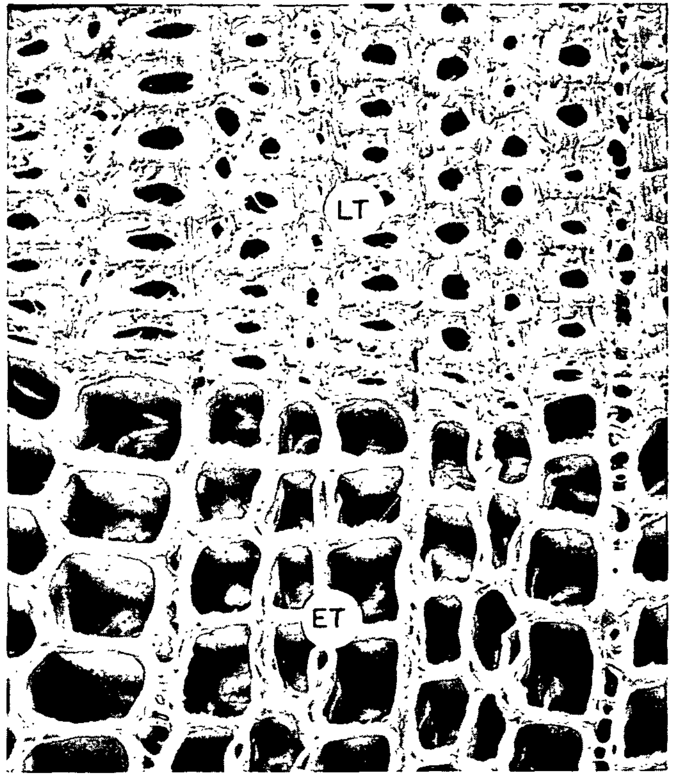

Figure 3. Photomicrograph (SEM) of Transverse Surface of Slash Pine, Ala. (IPC — 3033-10). Latewood Tracheids (LT), Earlywood Tracheids (ET). Magnification — 400 Diameters

TABLE V

WEIGHT FACTORS — SOUTHERN PINE

Pulp No.	Pulp Sample	Av. Wood Density, lb./cu.ft.	Screened Yield, %	Kappa No.	Pulp Weight Factor[a] Analyst A Mean	Pulp Weight Factor[a] Analyst B Mean	Average
1	Slash-mature-kraft (No. 1225A)	28.66	46.13	37.3	1.44	1.31	1.38
2	Slash-juvenile-kraft (No. 1225B)	26.82	44.85	38.5	1.31	1.30	1.30
3	Slash-mature-kraft (No. 1223B)	28.66	47.20	42.9	1.36	--	1.36
4	Slash-mature-kraft (No. 1221B)	28.66	45.72	38.7	1.42	--	1.42
5	Loblolly-juvenile-kraft (No. 1221A)	26.11	44.89	38.8	1.22	1.27	1.24
6	Loblolly-mature-kraft (No. 1230A)	28.71	46.38	40.8	1.44	1.56	1.50
7	Slash-mature-kraft (No. 1228A)	28.66	53.84	95.1	1.73	1.59	1.66
8	Slash-juvenile-kraft (No. 1228B)	26.82	52.00	90.6	1.53	1.39	1.46
9	Loblolly-mature-kraft (No. 1232A)	28.71	52.05	90.7	1.74	1.59	1.66
10	Loblolly-juvenile-kraft (No. 1232B)	26.11	51.07	93.2	1.49	1.55	1.52
11	Slash-mature-kraft (No. 1236A)	28.66	54.82	114.9	2.04	1.86	1.95
12	Loblolly-juvenile-kraft (No. 1236B)	26.11	54.90	115	1.55	1.66	1.60
13	Slash-juvenile-kraft (No. 1238B)	26.82	53.61	115	1.72	1.66	1.69
14	Loblolly-mature-kraft (No. 1241B)	28.71	55.13	115.4	1.57	1.65	1.61
15	Slash pine (No. 503) — kraft (No. 14)	--	--	--	1.75	1.92	1.84
16	Loblolly pine (No. 502) — kraft (No. 15)	--	--	--	1.76	1.79	1.78
17	Loblolly pine (No. 3033-11) — kraft (No. 3)	--	43.6	19	1.40	1.52	1.46
18	Loblolly pine (No. 3033-9) — kraft (No. 3)	--	46.0	18	1.33	1.52	1.42
19	Slash pine (No. 3033-10) — kraft (No. 3)	--	42.1	22	1.46	1.56	1.51
20	Slash pine (Fibrary Sample No. 128) — kraft	--	--	--	1.75	1.77	1.76
21	Loblolly pine (Hammermill) — bl. kraft	--	--	--	1.24	1.26	1.25
22	Sou. yellow pine (Riegel) — bl. kraft	--	--	--	1.45	1.47	1.46
23	Sou. yellow pine (Riegel) — Alpha Grade of bleached kraft (mercerized)	--	--	--	1.50	1.59	1.54
24	Longleaf pine, Fla. (Fibrary Sample No. 306) — kraft (soft cook)	--	--	--	1.43	--	1.43
25	Southern pine — Buckeye dissolving grade — bl. kraft	--	--	--	1.46	--	1.46
26	Shortleaf pine, Ala. (Fibrary Sample No. 387) — kraft (soft cook)	--	--	--	1.30	--	1.30
27	Loblolly pine — kraft	--	--	--	1.52	1.67	1.60

[a]The average standard deviation of the mean ($s_{\bar{x}}$) for Analyst A is 0.068 and Analyst B 0.070.

Photomicrographs of the fiber furnish of several pulp samples prepared from southern yellow pine are illustrated in Fig. 4-13. The two types of fibers, thick-walled latewood tracheids and thin-walled earlywood tracheids, are nearly as obvious in the photomicrographs of the pulp samples as they are in the photomicrographs prepared of the transverse surfaces of the wood specimens. The pulp samples are very similar in appearance as would be expected, with the possible exception of the sample of mercerized alpha grade of bleached kraft pulp (Fig. 13).

The slash and loblolly pine pulp samples supplied by Great Northern Paper Company (Pulps No. 1-14) turned out to be very useful in examining the influence of the "degree of delignification" on weight factor. The relationship between delignification and weight factor was examined by plotting weight factor vs. Kappa number and weight factor vs. screened yield (Fig. 14). Highly significant positive correlations were obtained between weight factor and Kappa number (R = 0.82) and weight factor and screened pulp yield (R = 0.84)*. Reducing the degree of delignification (high Kappa number) increased the pulp yield and resulted in higher than average weight factors.

One additional comparison was made using the Great Northern data and this involved comparing slash pine vs. loblolly pine and mature wood vs. juvenile wood. To do this on as meaningful a basis as possible, all data were adjusted to a 50% yield basis using the linear regression equation given in Fig. 14. Table VI summarizes the results of the comparisons. Loblolly pine and slash pine at comparable yield levels had very similar weight factors. For both slash and loblolly pine the juvenile wood weight factors were slightly lower than the mature wood. Knowing either pulp yield or Kappa number would make possible the selection of the most appropriate weight factor.

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*An R value greater than 0.66 is considered to be significant at the 1% level of probability.

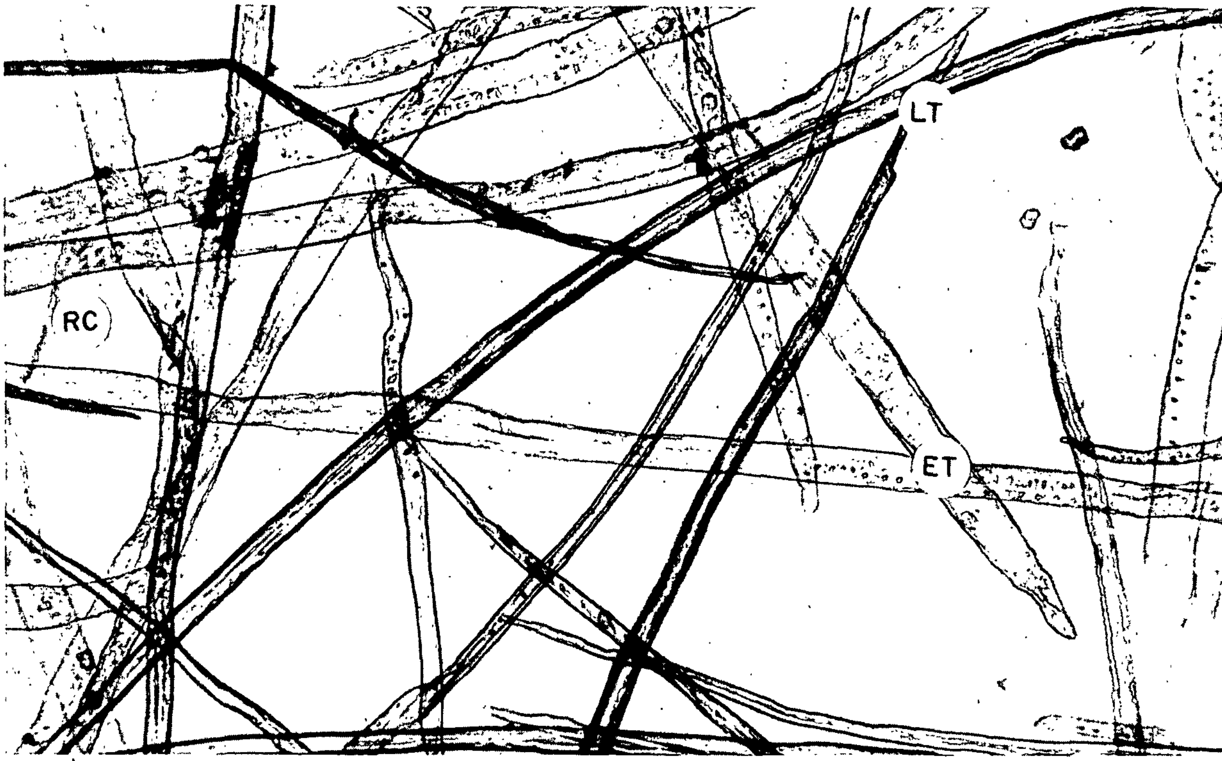


Figure 4. Pulp Sample of Slash Pine-Mature Wood-Unbleached Kraft. Screened Yield 53.84%; 90 Kappa No. Weight Factor 1.66. Latewood Tracheids (LT), Earlywood Tracheids (ET), Ray Cells (RC). Magnification — 90 Diameters

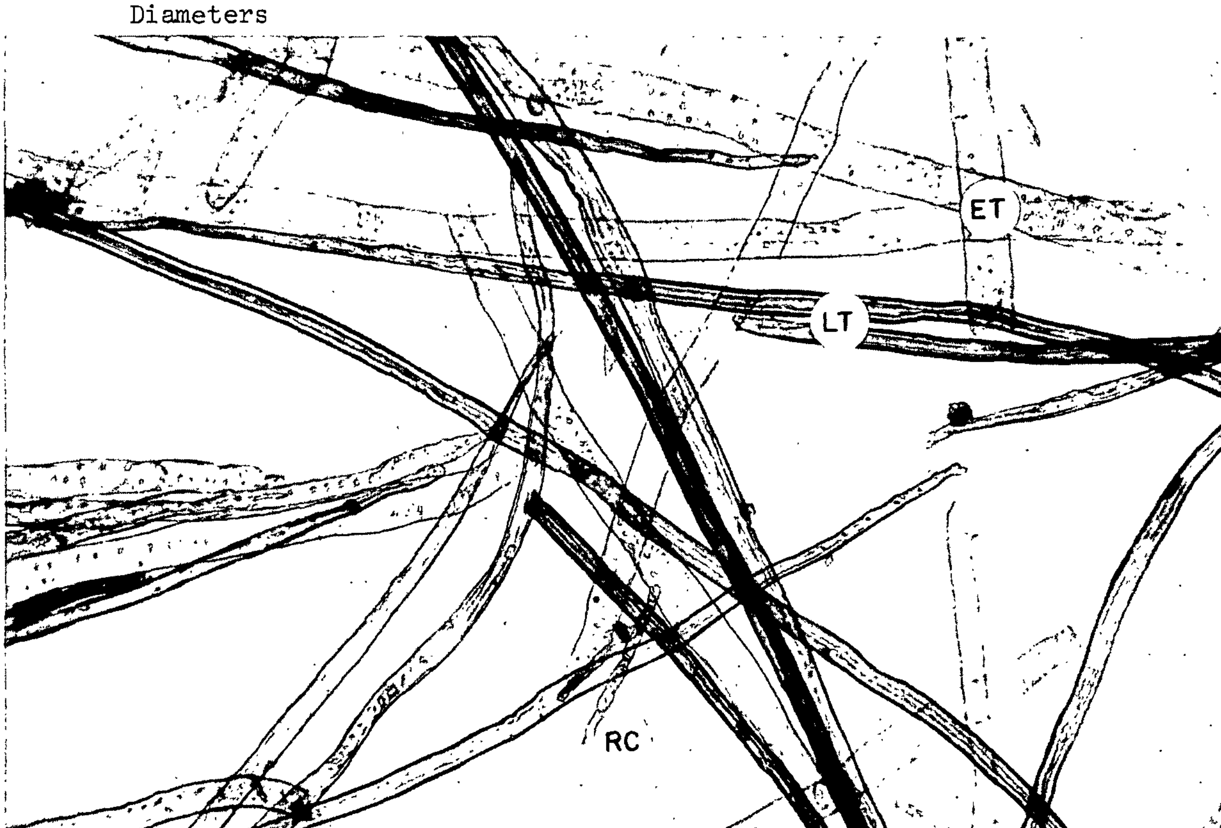


Figure 5. Pulp Sample of Slash Pine-Juvenile Wood-Unbleached Kraft. Screened Yield 52.00%; 90 Kappa No. Weight Factor 1.46. Latewood Tracheids (LT), Earlywood Tracheids (ET), Ray Cells (RC). Magnification — 90 Diameters

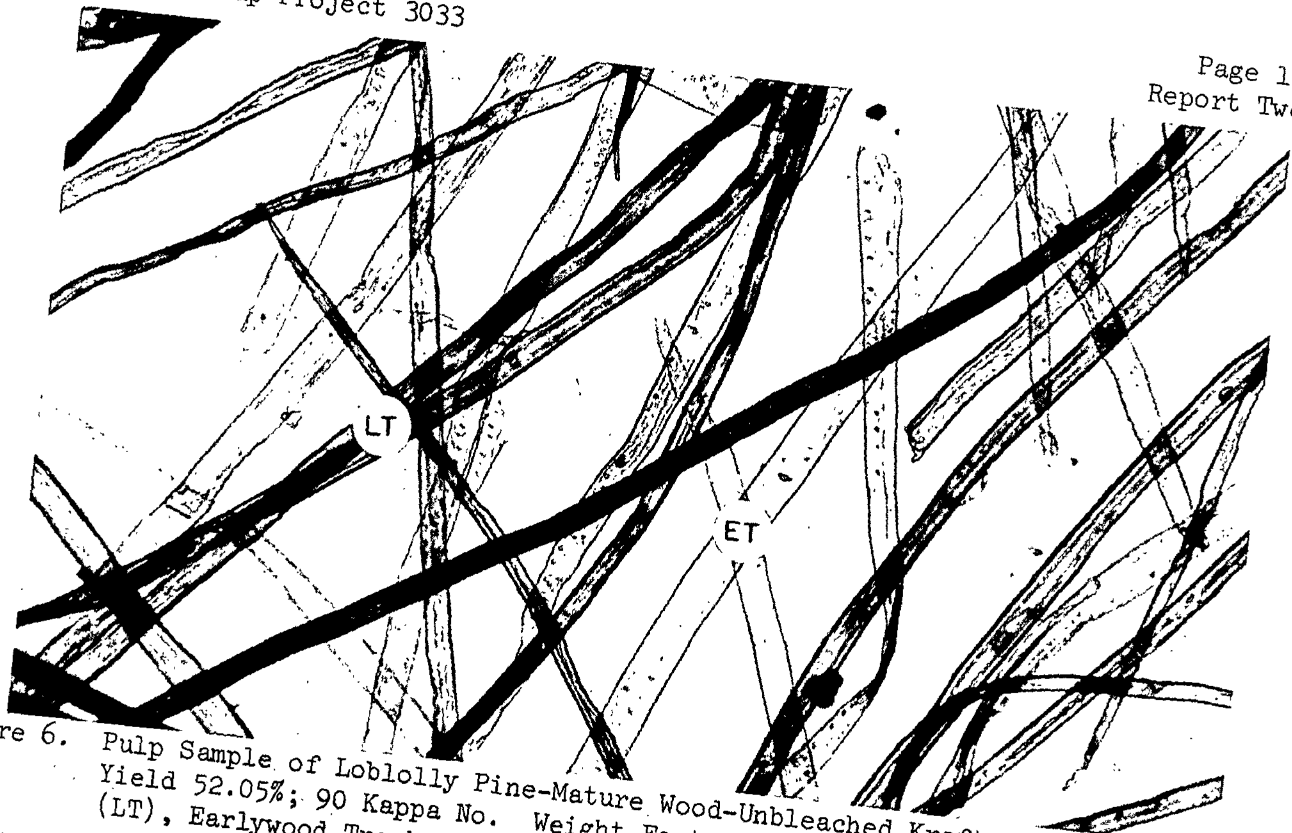


Figure 6. Pulp Sample of Loblolly Pine-Mature Wood-Unbleached Kraft. Screened Yield 52.05%; 90 Kappa No. Weight Factor 1.66. Latewood Tracheids (LT), Earlywood Tracheids (ET). Magnification — 90 Diameters

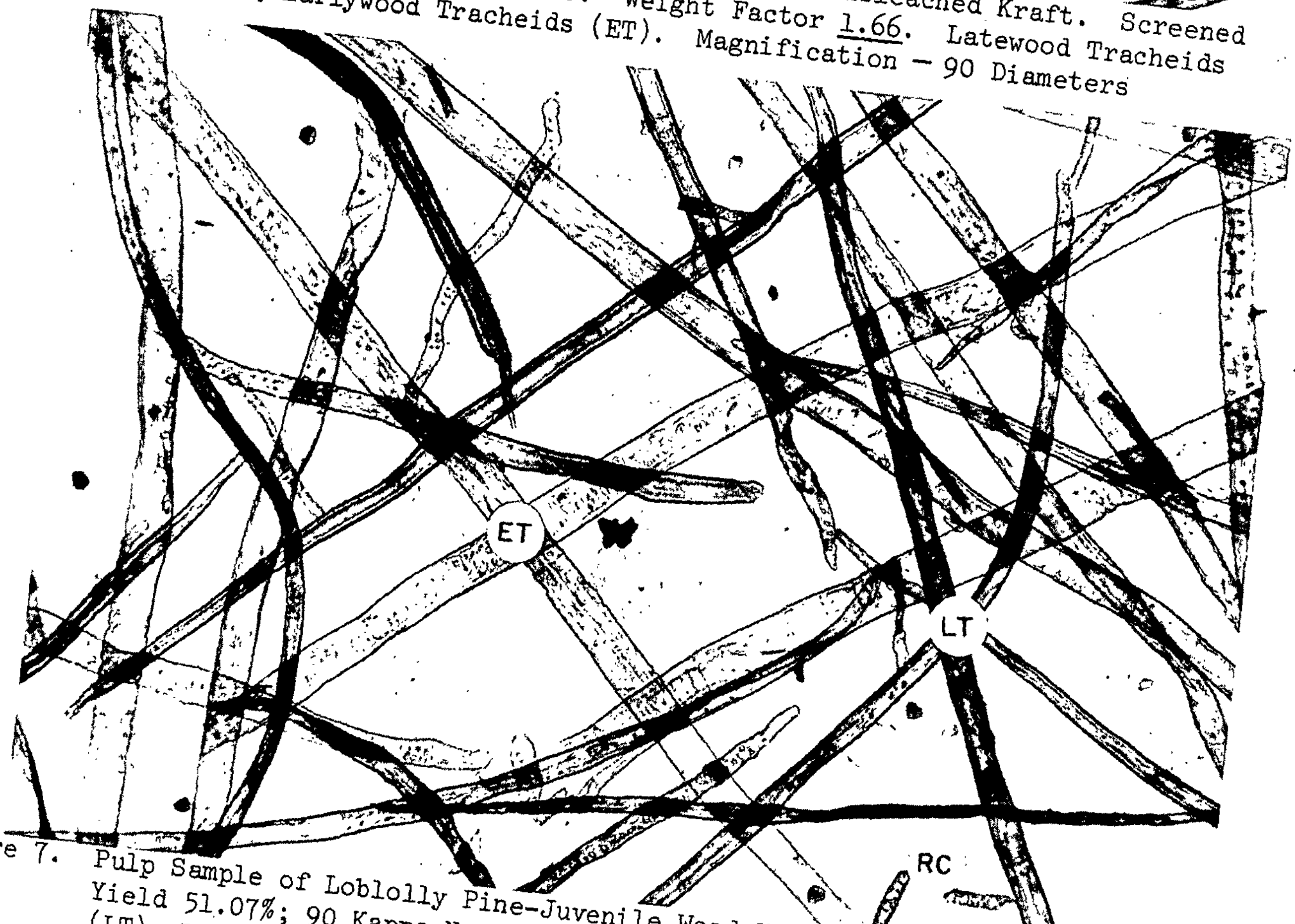


Figure 7. Pulp Sample of Loblolly Pine-Juvenile Wood-Unbleached Kraft. Screened Yield 51.07%; 90 Kappa No. Weight Factor 1.52. Latewood Tracheids (LT), Earlywood Tracheids (ET), Ray Cells (RC). Magnification — 90 Diameters

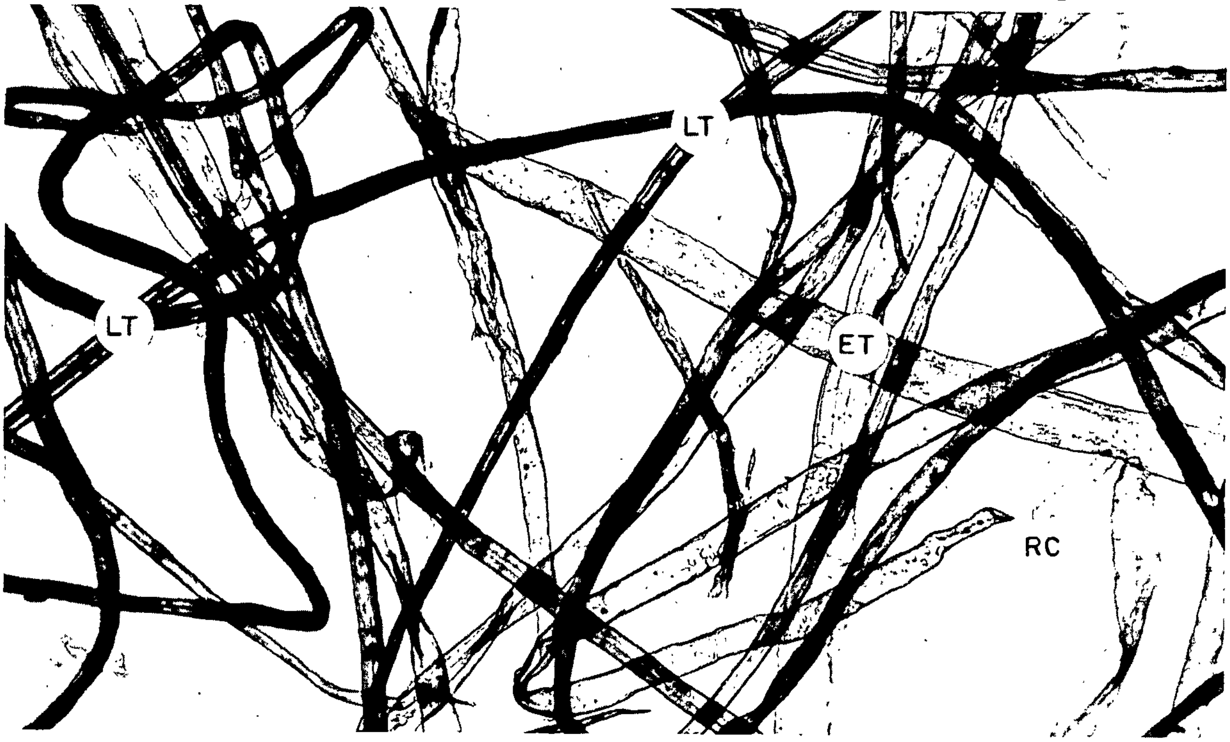


Figure 8. Pulp Sample of Loblolly Pine, Miss.-Unbleached Kraft. Weight Factor 1.78. Latewood Tracheids (LT), Earlywood Tracheids (ET). Magnification — 90 Diameters

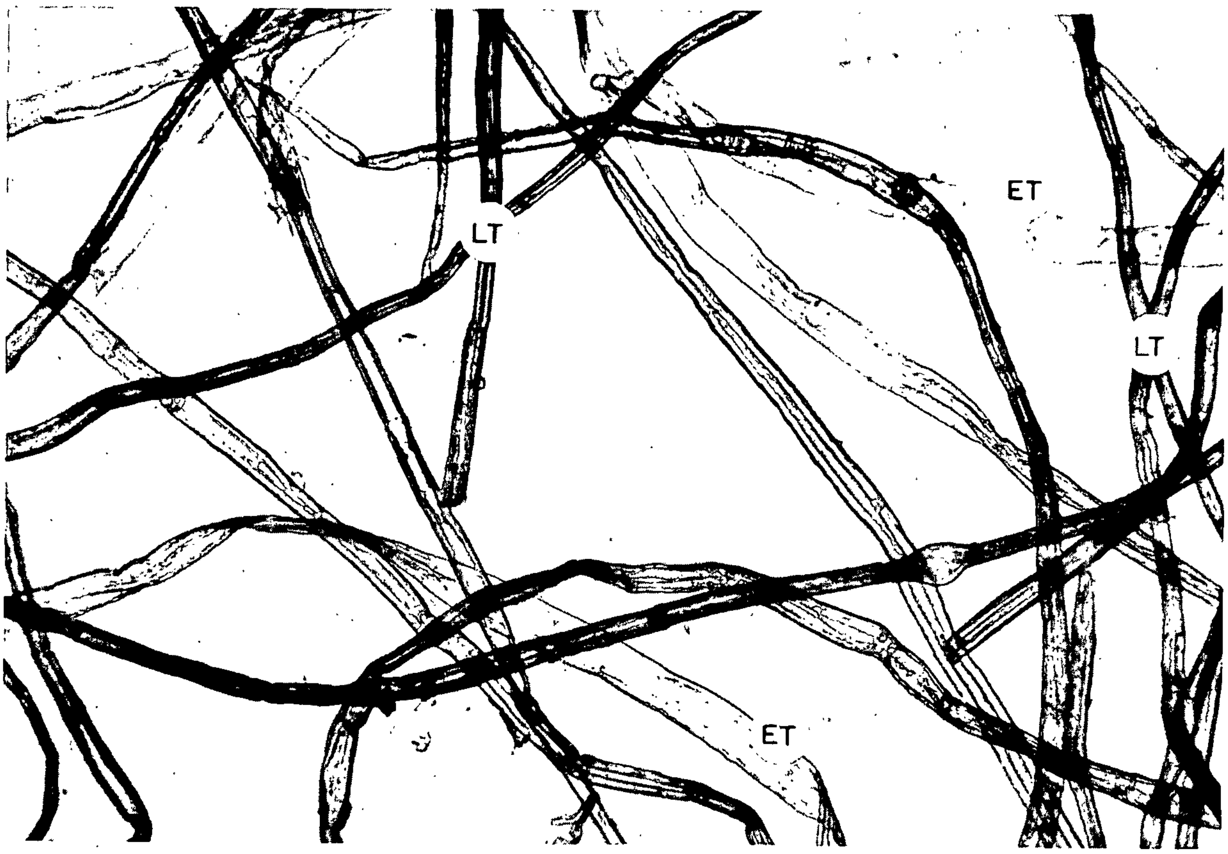


Figure 9. Pulp Sample of Slash Pine, Miss.-Unbleached Kraft. Weight Factor 1.84. Latewood Tracheids (LT), Earlywood Tracheids (ET). Magnification — 90 Diameters

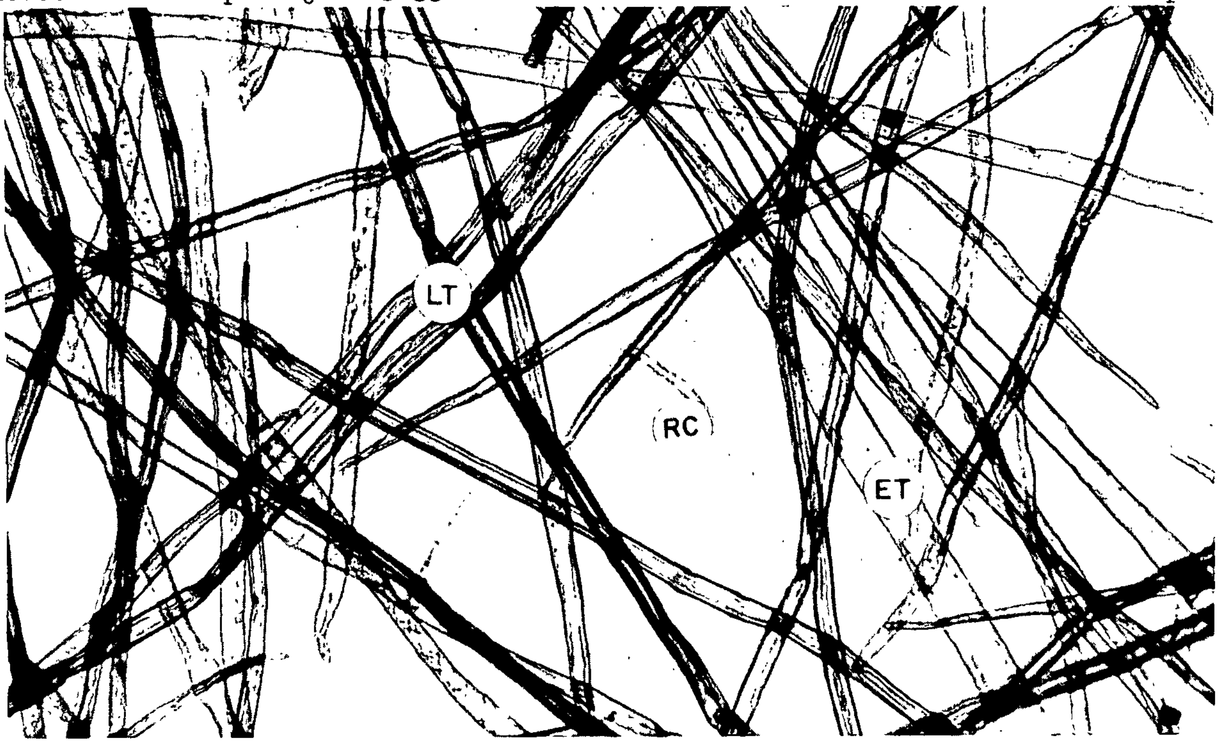


Figure 10. Pulp Sample of Loblolly Pine, La.-Unbleached Kraft. Screened Yield 46.0%; 18 Kappa No. Weight Factor 1.42. Latewood Tracheids (LT), Earlywood Tracheids (ET), Ray Cells (RC). Magnification — 90 Diameters

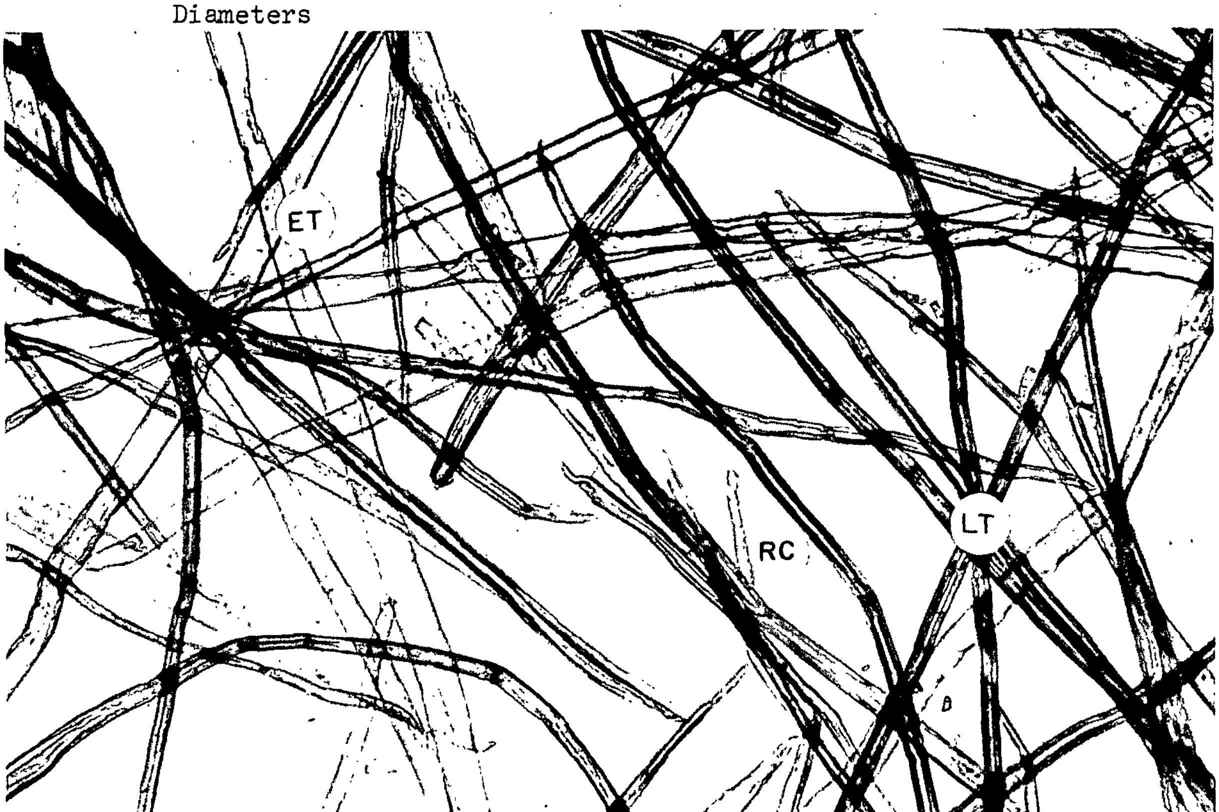


Figure 11. Pulp Sample of Loblolly Pine, Ga.-Unbleached Kraft. Screened Yield 43.6%; 19 Kappa No. Weight Factor 1.46. Latewood Tracheids (LT), Earlywood Tracheids (ET), Ray Cells (RC). Magnification — 90 Diameters

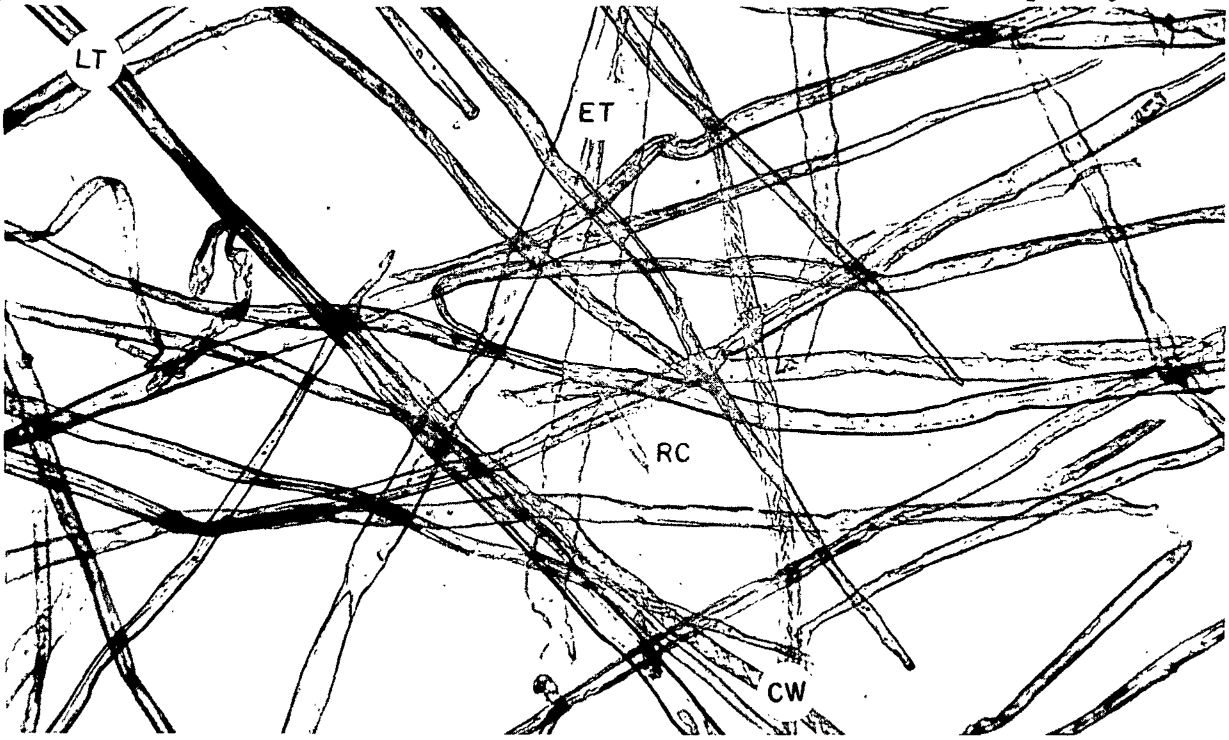


Figure 12. Pulp Sample of Slash Pine, Ala.-Unbleached Kraft. Screened Yield 42.1%; 22 Kappa No. Weight Factor 1.51. Latewood Tracheids (LT), Earlywood Tracheids (ET), Compression Wood Tracheids (CW), Ray Cells (RC). Magnification — 90 Diameters

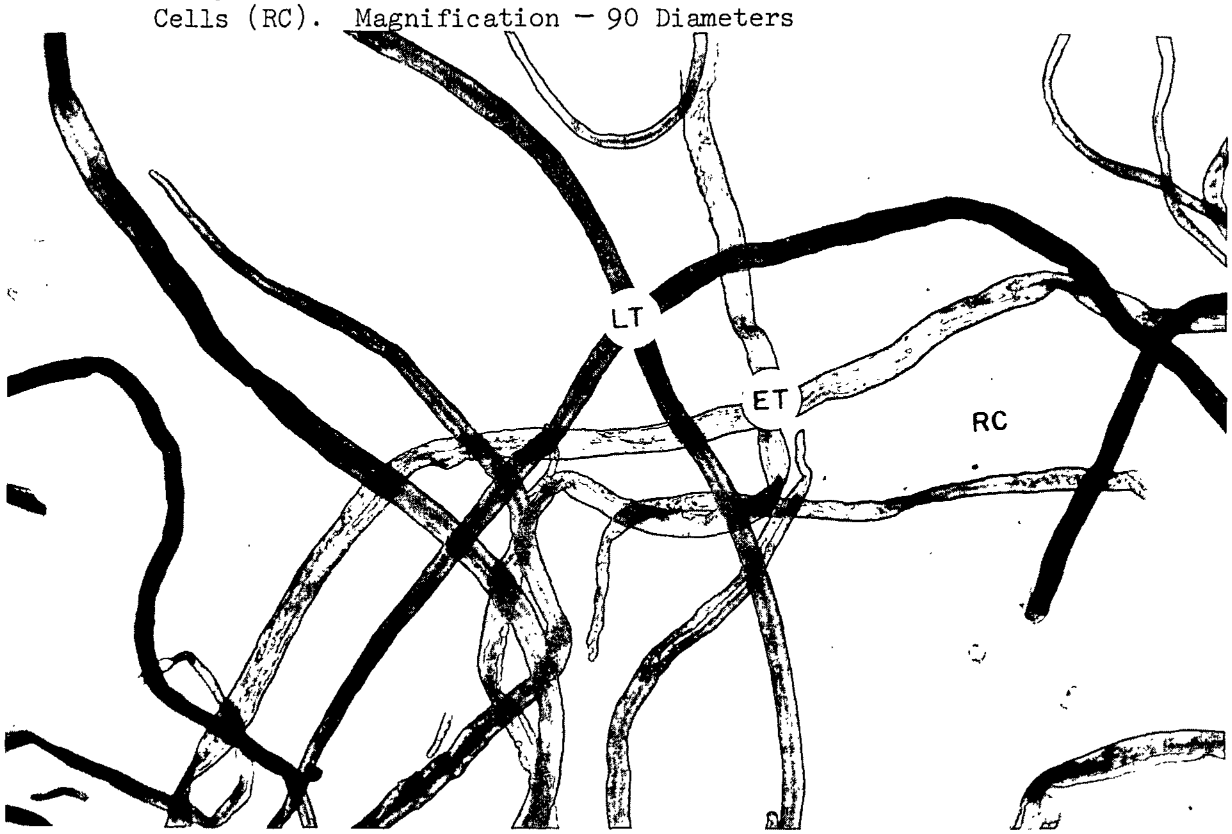
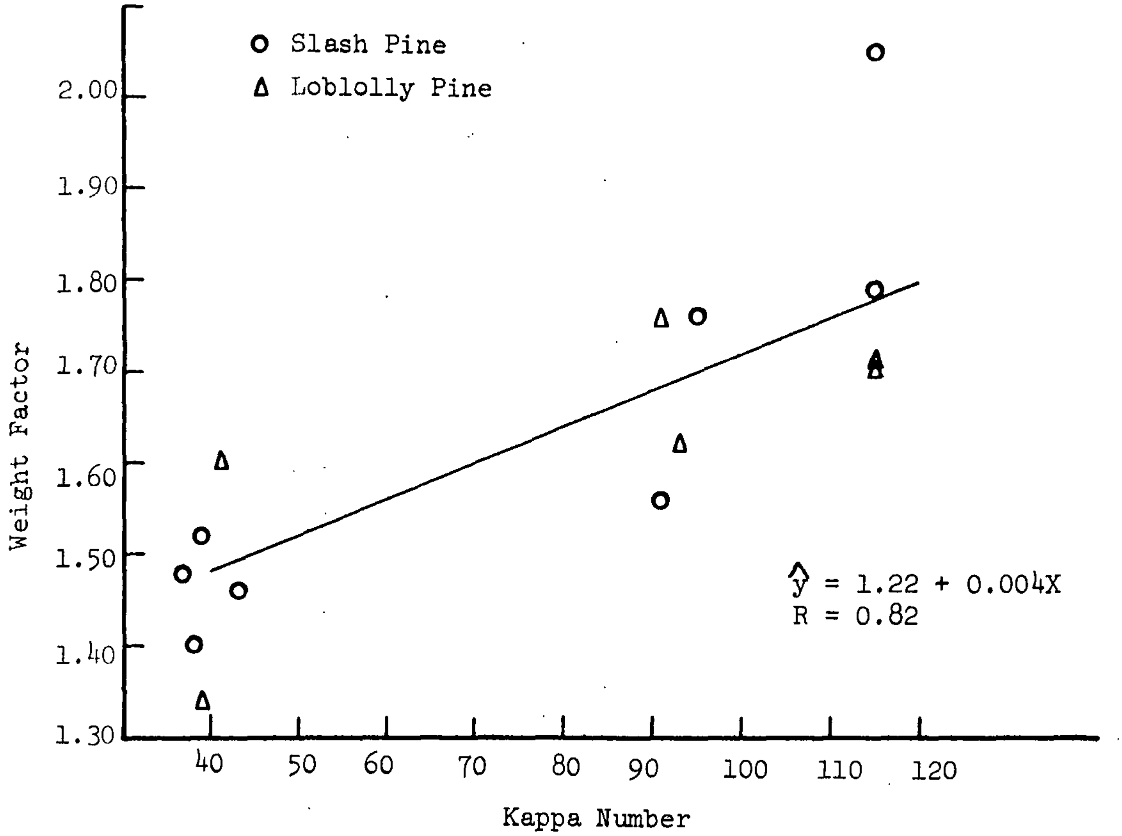


Figure 13. Pulp Sample of Southern Yellow Pine Alpha Grade of Bleached Kraft-Mercerized. Weight Factor 1.54. Latewood Tracheids (LT), Earlywood Tracheids (ET), Ray Cells (RC). Magnification — 90 Diameters



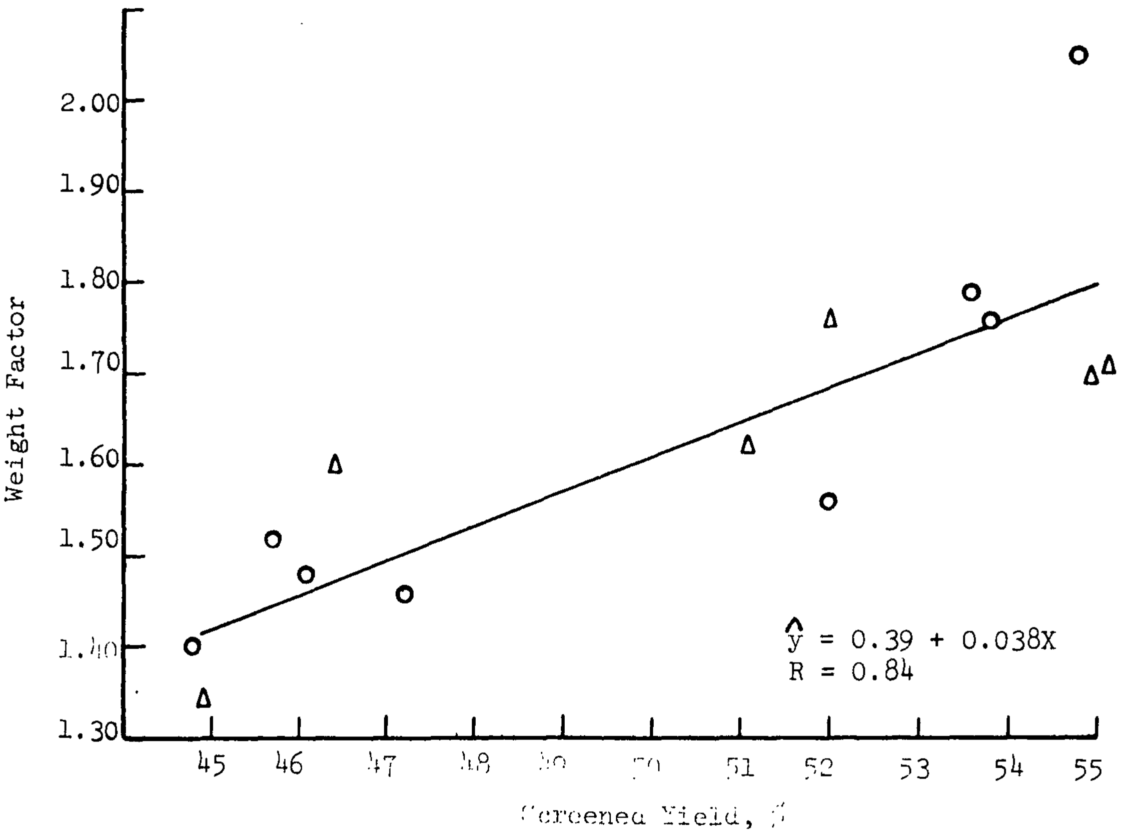


Figure 14. Highly Significant Correlations were Obtained Between Weight Factor and Kappa Number (Above) and Weight Factor and Screened Yield (Below). The Regression Equations Provide a Method that Allows the Selection of Appropriate Weight Factors for Southern Pine when Either Pulp Yield or Kappa Number is Known.

TABLE VI

SLASH AND LOBLOLLY PINE WEIGHT FACTORS ADJUSTED TO 50% PULP YIELD

Species	Age	Original	Adjusted[a]
Slash pine	Mature	1.38	1.53
	Mature	1.36	1.47
	Mature	1.42	1.58
	Mature	1.66	1.51
	Mature	1.95	1.77
	$\bar{x}$	1.55	1.57
Slash pine	Juvenile	1.30	1.49
	Juvenile	1.46	1.38
	Juvenile	1.69	1.55
	$\bar{x}$	1.48	1.47
Loblolly pine	Mature	1.50	1.64
	Mature	1.66	1.58
	Mature	1.61	1.42
	$\bar{x}$	1.59	1.55
Loblolly pine	Juvenile	1.24	1.43
	Juvenile	1.52	1.46
	Juvenile	1.60	1.41
	$\bar{x}$	1.45	1.43

[a]Adjusted weight factors obtained by using the regression equation relationship shown in Fig. 14.

SPECIES OF OAK

WHITE OAK

General Description and Minute Anatomy of Wood Species

The wood of species of white oak is heavy to very heavy (sp.gr. 0.55-0.64 green, 0.66-0.79 ovendry). The wood is typically ring porous, containing large earlywood pores distinctly visible to the naked eye, forming a conspicuous band 1-3 pores in width. The pores are frequently occluded with tyloses in the heartwood. The transition from early to latewood is abrupt or somewhat gradual. The latewood pores are numerous, small, and not sharply defined with a hand lens. There are two types of rays present in the species, broad (oak type) and narrow. The broad rays are very distinct to the naked eye and are separated by several to many narrow rays which are indistinct without magnification. There are between 20-120 latewood vessels per sq. mm. The largest earlywood vessels are 180-380 µm. in diameter and average approximately 0.40 mm. in length. The fibers are medium thick to thick-walled, frequently gelatinous, 14-22 micrometers in diameter and 1.4 mm. in length. Paratracheal, apotracheal-diffuse and banded parenchyma are abundant and visible with a hand lens. Vasicentric tracheids are present, intermingled with parenchyma. The rays are unstoried and homogeneous. The broad rays are 12 to 30 plus seriate, 150-400+ micrometers wide through the central portion and many cells (into hundreds) in height. The narrow rays are numerous, uniseriate or occasionally in part biseriate, very variable in height (1-20 plus cells).

Species of the various oaks belonging to the white oak group (Leucobalanus) cannot be identified from one another with certainty.

RED OAK

General Description and Minute Anatomy of Wood Species

The wood of red oak is similar to that described for white oak species except for the following:

1. The transition from earlywood to latewood is generally more gradual for species of red oak.
2. The earlywood pores in the heartwood of red oak species are usually not occluded with tyloses.
3. The latewood pores in the red oaks are plainly visible with a hand lens and are thick-walled. There are only 10 to 30 vessels per sq. mm. as compared with 12 to 120 vessels per sq. mm. for species of white oak. The largest earlywood vessels in red oak species are 200-430 μm. in diameter.
4. The large rays in species of red oak average 0.25 to 0.5 inch high and rarely more than 1.5 inches.

The woods of the various red oaks belonging to the red oak group (Erythrobalanus) cannot be identified with certainty.

Photomicrographs of transverse surface areas prepared from wood samples of species of white and red oak are illustrated in Fig. 15-18.

Weight Factor Determination

The weight factor determinations which have been made on pulps prepared from species of oak are listed in Table VII.

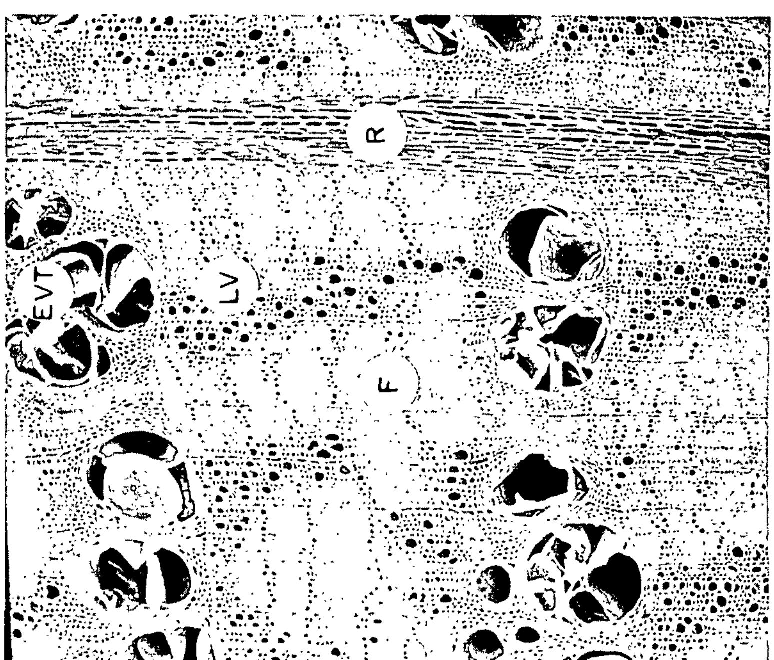


Figure 15. Photomicrograph (SEM) of Transverse Surface of White Oak, Va. Earlywood Vessels with Tyloses (EVT), Latewood Vessels (LV), Fibers (F), Ray (R). Magnification — 50 Diameters

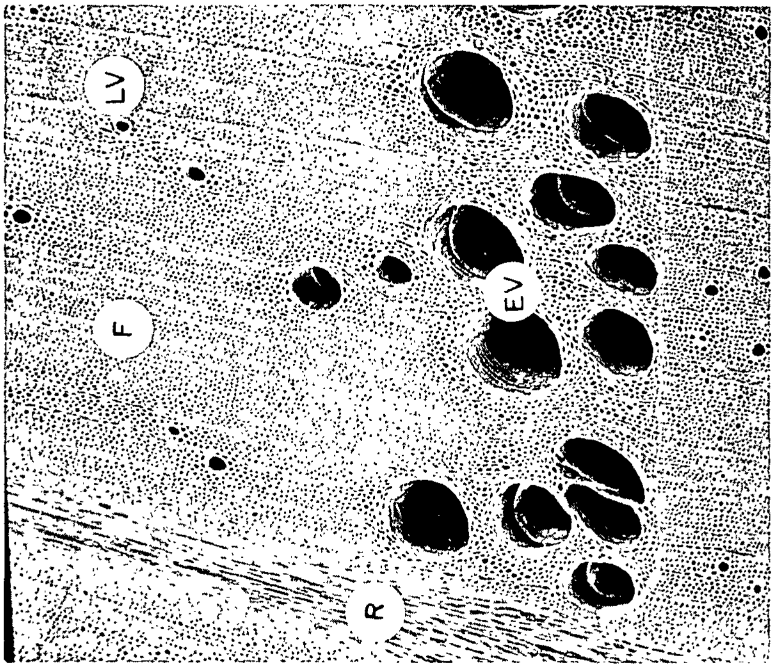


Figure 16. Photomicrograph (SEM) of Transverse Surface of Red Oak, N. Wis. Earlywood Vessels (EV), Latewood Vessels (LV), Fibers (F), Ray (R). Magnification — 50 Diameters

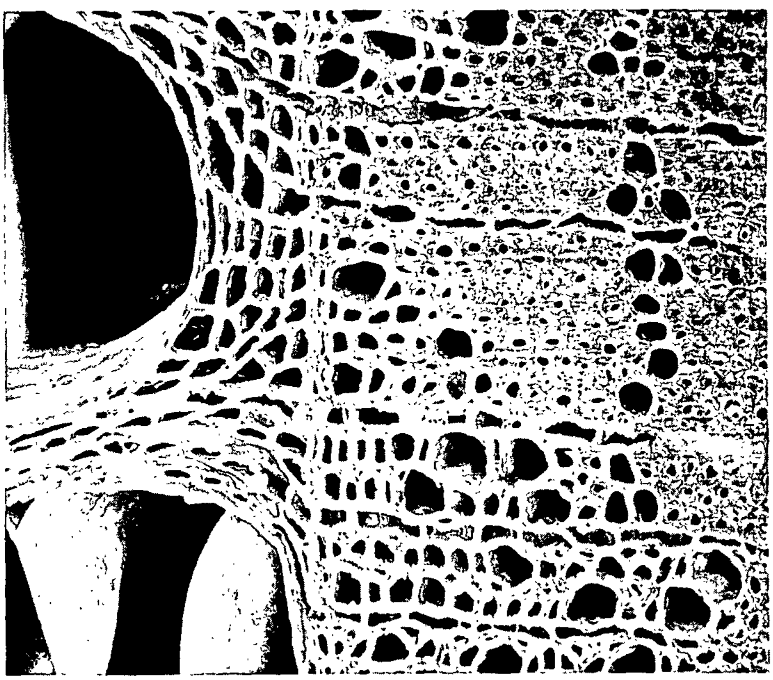


Figure 17. Photomicrograph (SEM) of Transverse Surface of White Oak, Va. Magnification — 300 Diameters

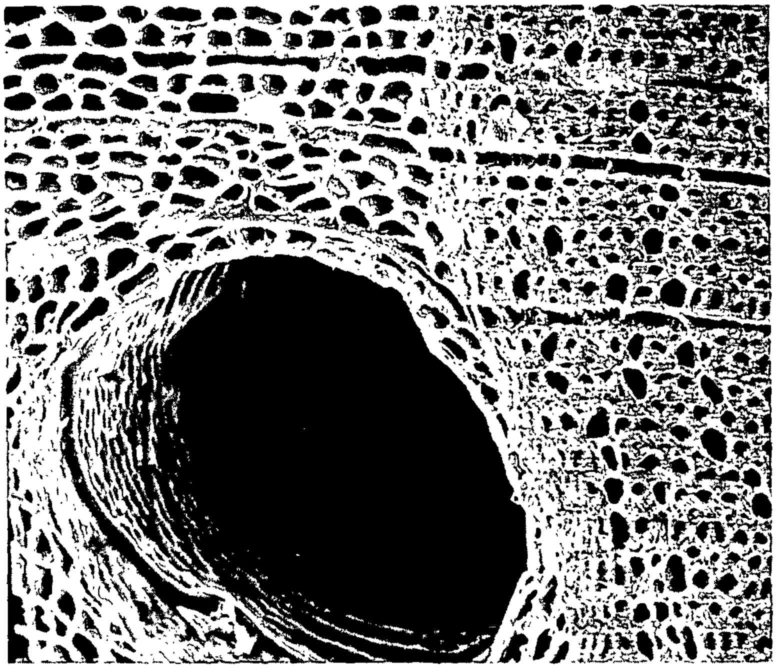


Figure 18. Photomicrograph (SEM) of Transverse Surface of Red Oak, N. Wis. Magnification — 300 Diameters

TABLE VII

WEIGHT FACTORS — SPECIES OF OAK

Pulp No.	Pulp Sample	Yield, % o.d. basis	Kappa No.	Pulp Weight Factor[a] Analyst A Mean	Analyst B Mean	Average
1	White Oak, Wis. — unbleached kraft (IPC No. 3033-24)	44.8	9	0.49	0.49	0.49
2	White Oak, Va. — unbleached kraft (IPC No. 3033-19)	45.1	>9	0.42	0.47	0.44
3	White Oak, La. — unbleached kraft (Riegel Paper Corp., Sample No. 928)	--	--	0.41	0.40	0.40
4	White Oak, Ala. — bleached kraft (Hammermill Paper Co., CEDED bleach)	--	15	0.49	0.49	0.49
5	White Oak, Penn. — bleached soda (Hammermill Paper Co., CEDED bleach)	--	14	0.46	0.47	0.46
6	Bur Oak, Central Wis. — unbleached kraft (IPC No. 3033-13)	48.1	>9	0.42	0.45	0.44
7	Post Oak, Ala. — unbleached kraft (IPC No. 3033-15)	45.3	16	0.44	0.46	0.45
8	Water Oak, Ala. — bleached kraft (Hammermill Paper Co., CEDED bleach)	--	13	0.43	0.43	0.43
9	Southern Red Oak, Va. — unbleached kraft (IPC No. 3033-20)	47.9	>9	0.55	0.50	0.52
10	Southern Red Oak, Ala. — unbleached kraft (IPC No. 3033-14)	49.2	>9	0.51	0.53	0.52
11	Red Oak, Northern Wis. — unbleached kraft (IPC No. 3033-6)	50.2	>9	0.40	0.44	0.42
12	Northern Red Oak, N.H. — unbleached kraft (Riegel Paper Corp. Sample No. 611)	--	10.8	0.46	0.45	0.46
13	Red Oak, Ala. — bleached kraft (Hammermill Paper Co., CEDED bleach)	--	15	0.49	0.48	0.48
14	Red Oak, Penn. — bleached soda (Hammermill Paper Co., CEH bleach)	--	15	0.44	0.46	0.45
15	Narrow-leaf live oak — unbleached kraft	--	--	0.52	--	0.52
16	Species of Oak (Nekoosa-Edwards Paper Co., Sivola Process)	--	--	0.46	--	0.46
17	Northern Red Oak — bleached sulfite (Fibrary Sample No. 378)	--	--	0.48	--	0.48
18	Northern Red Oak — unbleached sulfite (Fibrary Sample No. 377)	--	--	0.48	--	0.48
19	White Oak — unbleached kraft (Fibrary Sample No. 296)	--	--	0.49	0.53	0.51

[a] The average standard deviation of the mean ($s_{\bar{x}}$) for both Analyst A and Analyst B is 0.016.

The weight factors of Pulps No. 4 and 13 were reported previously (Project 3033 — Progress Report One). The weight factor determinations for Pulp Samples 15 through 19 had been made before the initiation of Project 3033 by Institute personnel in a continuing study (IPC Project 1499) of the weight factors of various pulps and their application in fiber analysis.

The factors obtained for all pulp samples prepared from species of red and white oak were lower than the suggested factor of 0.6 (TAPPI Standard T 401 m-60). Results of this investigation suggest that 0.45-0.5 would be a more appropriate factor for most chemical pulps prepared from these wood species. The limited data available suggest that wood species and geographic location have little, if any, effect on pulps prepared from oak species. It was not possible to evaluate the influence of cooking conditions because of the limited number of samples with appropriate yield and Kappa number data.

Photomicrographs of the furnishes of several pulp samples prepared from species of white and red oak, showing the different types of cellular elements present in these pulps, are illustrated in Fig. 19 through 29. The many ray cells present in these pulps are not included in the counts when making a weight factor determination.

The fibers of species of oak are narrow, 14-22 μm., thick walled, and have an average fiber length of approximately 1.4 mm. The extremely large width of some of the earlywood vessel elements is quite obvious in some of the photomicrographs. Many of these elements may be lost or destroyed during pulp preparation.

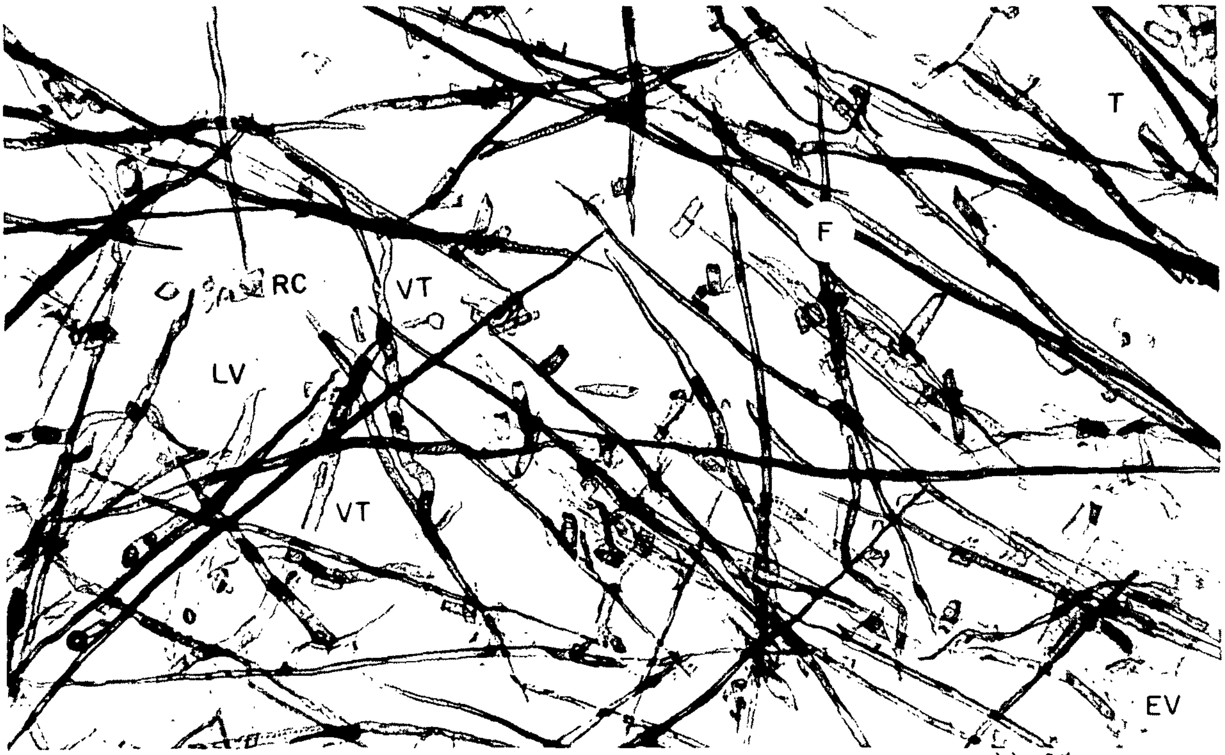


Figure 19. Pulp Sample of White Oak, Wis.-Unbleached Kraft. Yield 44.8%; 9 Kappa No. Weight Factor 0.49. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Vasicentric Tracheids (VT), Tylosis (T), Ray Cells (RC). Magnification — 90 Diameters

Figure 20. Pulp Sample of White Oak, Va.-Unbleached Kraft. Yield 45.1%; >9 Kappa No. Weight Factor 0.44. Earlywood Vessel Element (EV) with Tyloses (T), Latewood Vessel Element (LV), Fibers (F), Vasicentric Tracheids (VT), Ray Cells (RC). Magnification — 90 Diameters

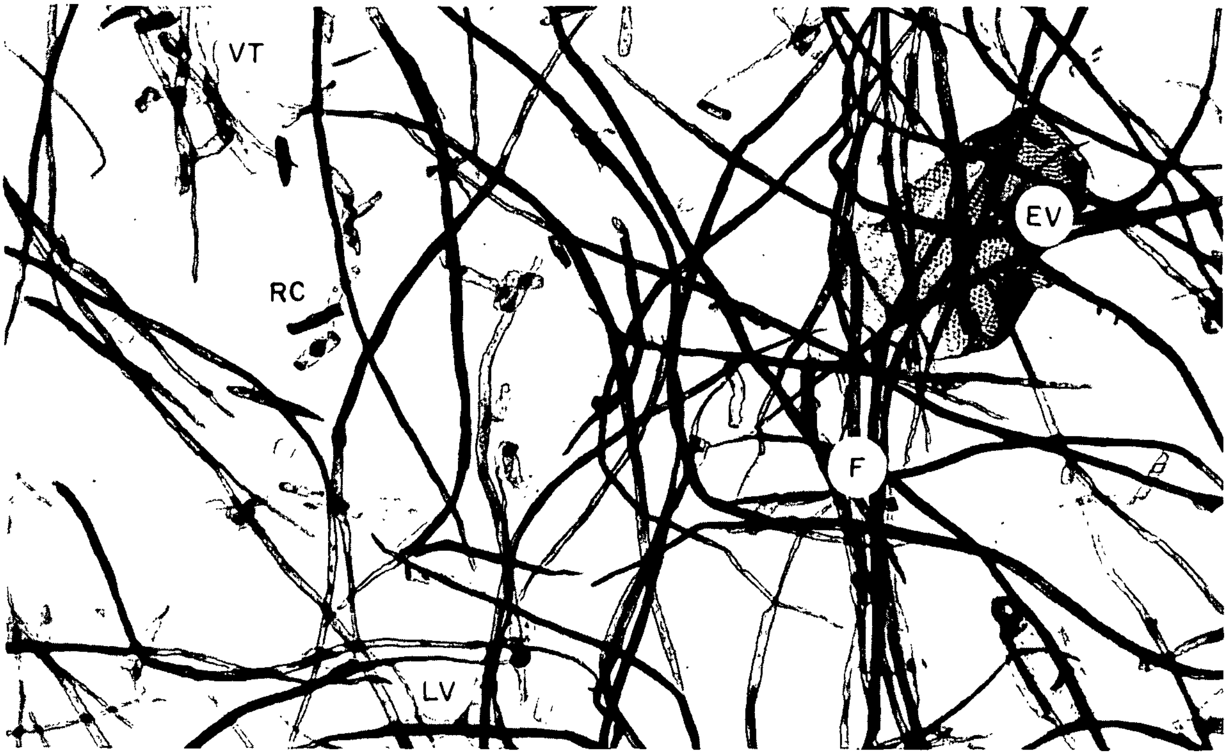


Figure 21. Pulp Sample of White Oak, La.-Unbleached Kraft. Kappa No. 12. Weight Factor 0.40. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Vasicentric Tracheids (VT), Ray Cells (RC). Magnification — 90 Diameters

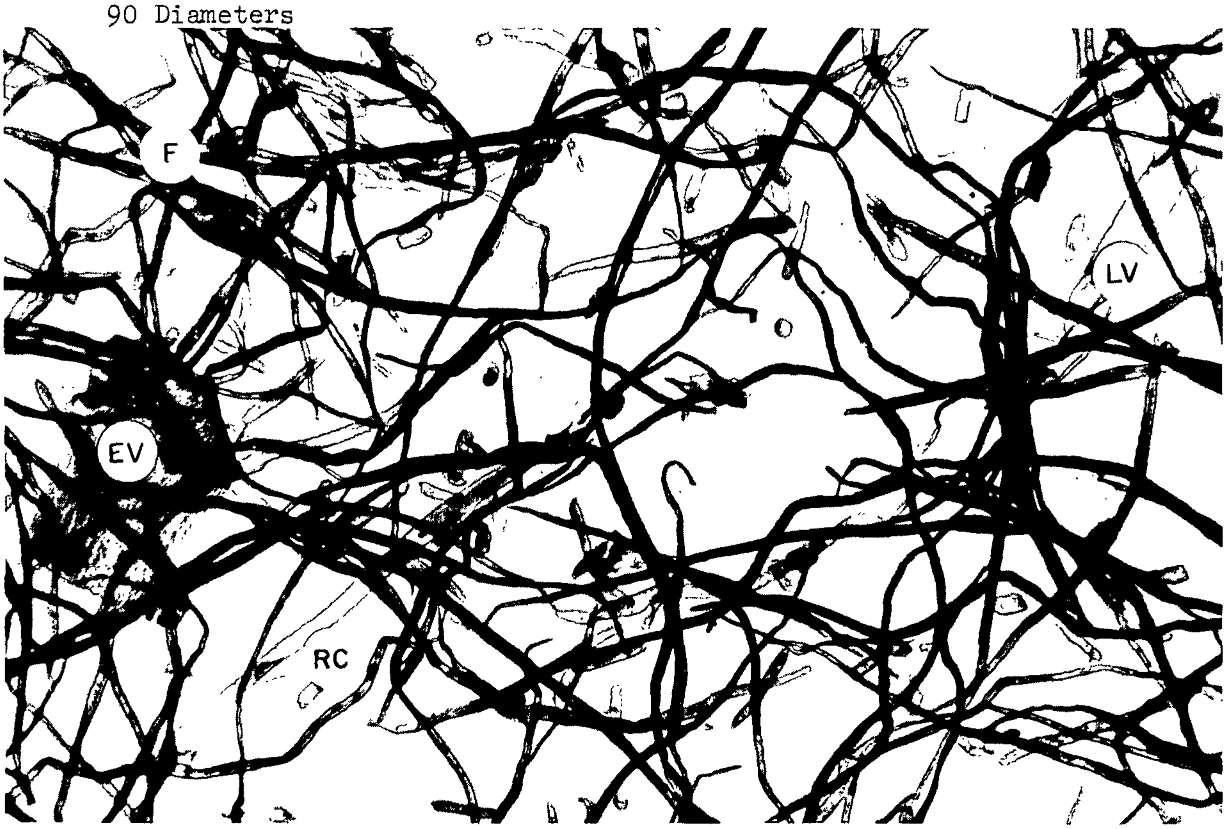


Figure 22. Pulp Sample of White Oak, Pa.-Bleached Soda. Kappa No. 14. Weight Factor 0.46. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters

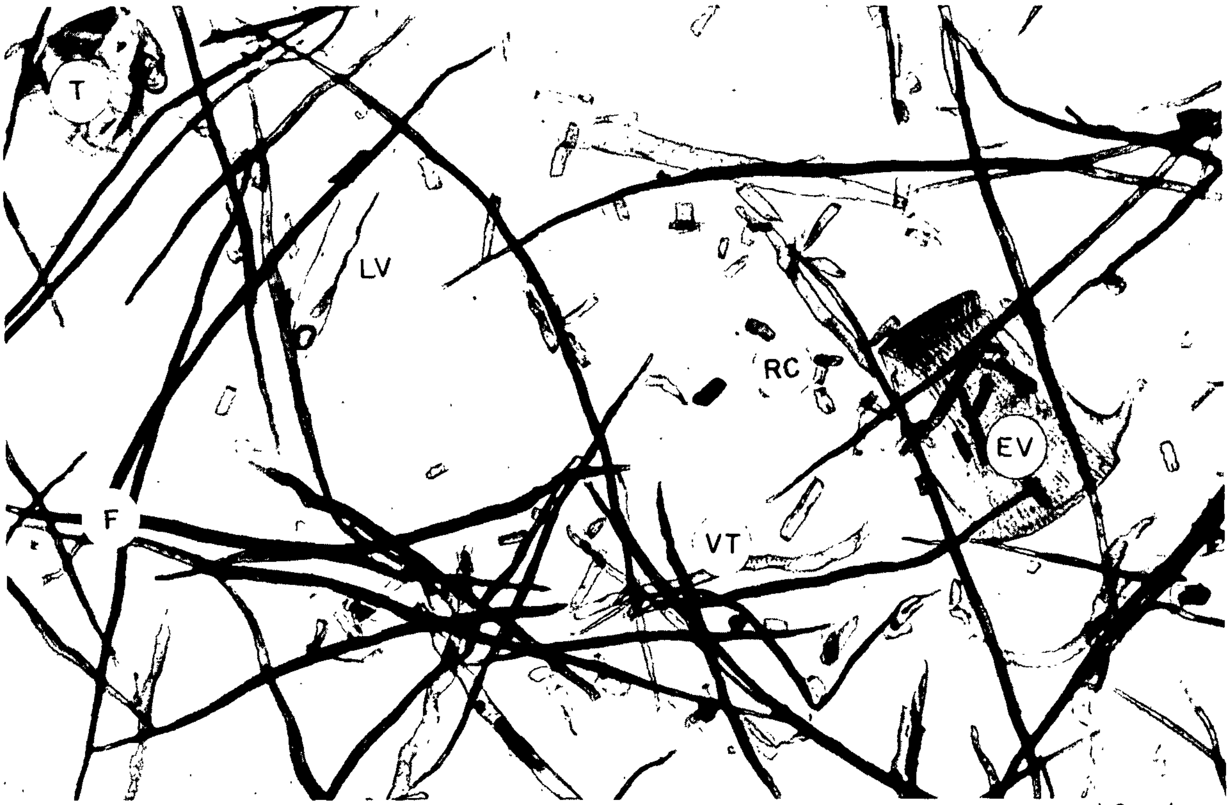


Figure 23. Pulp Sample of Bur Oak, Central Wis.-Unbleached Kraft. Yield 48.1%; Kappa No. >9. Weight Factor 0.44. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Vasicentric Tracheids (VT), Tylosis (T), Ray Cells (RC). Magnification — 90 Diameters

Figure 24. Pulp Sample of Post Oak, Ala.-Unbleached Kraft. Yield 45.3%; Kappa No. 16. Weight Factor 0.45. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Tylosis (T), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters

Figure 25. Pulp Sample of Water Oak, Ala.-Bleached Kraft. Kappa No. 13. Weight Factor 0.43. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Vasicentric Tracheids (VT), Ray Cells (RC). Magnification — 90 Diameters

Figure 26. Pulp Sample of Southern Red Oak, Va.-Unbleached Kraft. Yield 47.9%; 10 Kappa No. Weight Factor 0.52. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters

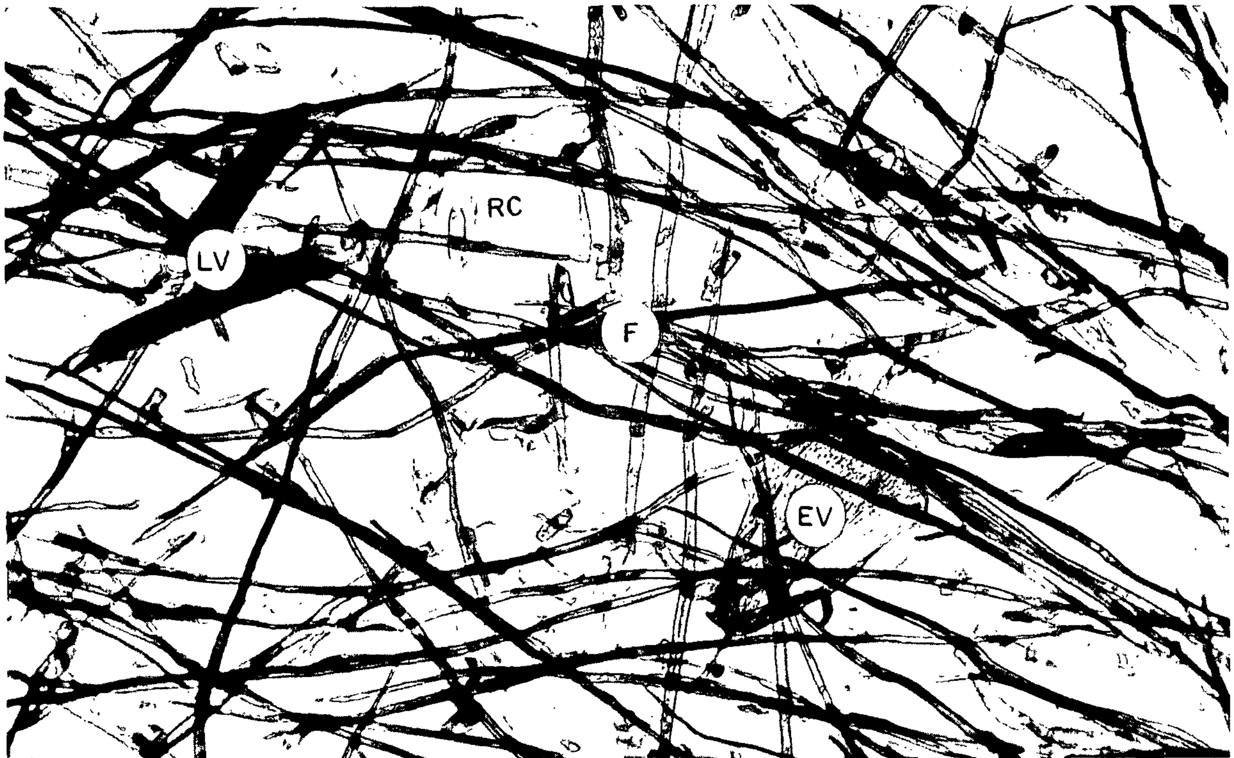


Figure 27. Pulp Sample of N. Red Oak, N. Wis.-Unbleached Kraft. Yield 50.2%; 10 Kappa No. Weight Factor 0.42. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters

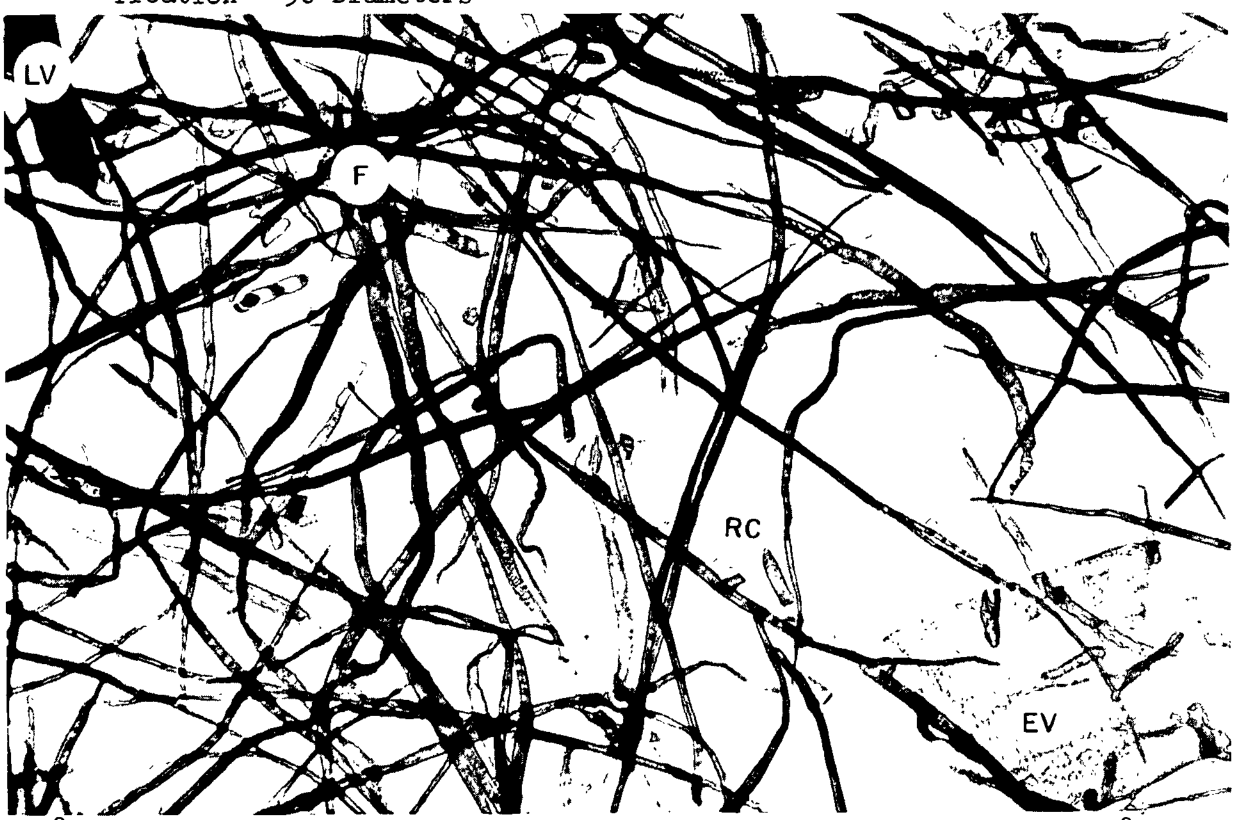


Figure 28. Pulp Sample of N. Red Oak, N.H.-Unbleached Kraft. Kappa No. 10.8. Weight Factor 0.46. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters

Figure 29. Pulp Sample of Red Oak, Pa.-Bleached Soda. Kappa No. 15. Weight Factor 0.45. Earlywood Vessel Element (EV), Latewood Vessel Element (LV), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters

DISCUSSION OF RESULTS

The results of previous investigations by Landes (3) and Graff (4) revealed that the weight factors of pulps show marked variation between species of wood and also between pulps of the same species but from different geographic locations. Relative to the investigations of the weight factors of pulp samples, there have been numerous studies on wood density and the correlation between specific gravity and pulp yields for various wood species. It has been reported (5, 6), for instance, that for every 0.02 increase of specific gravity, there is a corresponding increase of 50 pounds of dry processed pulp per cord of southern pine wood. It should be remembered that variations occur in specific gravity, fiber length, width, etc. within trees and between trees of any species. These variations may be considerably greater than any differences which may exist between stands and stands from different geographical areas. Numerous studies have shown, for example, that in southern pines, as in other wood species, the specific gravity tends to decrease with height in tree and to increase with distance from pith. In terms of geographic variability, on the other hand, a survey on southern wood density (7) revealed that only slash pine and longleaf pine showed a general trend of specific gravity increasing from north to south. Of the four species investigated (i.e., slash, loblolly, longleaf and shortleaf), shortleaf pine showed the least amount of variation in all the environmental categories evaluated.

The results of the present investigation, on the weight factors of various pulps, indicate that samples prepared from slash and loblolly juvenile wood, with lower average densities and % screened yields, also have slightly lower weight factor values than pulps prepared from the mature wood. The data available would indicate that there is no significant difference in the weight factors of pulps prepared from species of slash pine and similar pulps prepared from species of loblolly pine. The survey on southern wood density (7), however, reported that the average tree specific gravity values representing all trees 3 inches in diameter and above were estimated to be 0.53 for slash pine and 0.47 for loblolly pine. Slash pine pulps, on the average, are probably coarser than similar pulps prepared from species of loblolly pine and therefore should have a higher average weight factor value. Considerably more weight factor data would be necessary, however, to prove this theory.

There was not enough data available to determine if site and geographic location have any appreciable effect on the weight factor of pulps prepared from the same wood species. The pulp samples received from Great Northern Paper Co. were prepared from either species of slash or loblolly pine from several different origins. We assume, however, from the submitted data for these pulps, that the wood samples from the different sites were mixed together to constitute a single pulp sample for a given species and class (i.e., juvenile or mature). Figure 30 also shows that the sampling areas were fairly well concentrated in a more or less single geographic location.

The data presented demonstrated, quite conclusively, the influence of cooking conditions (degree of delignification) on weight factor. Cooking wood to low Kappa numbers (low yields) resulted, as might be expected, in pulps with lower than normal weight factors. Comparisons of weight factor information from loblolly and slash pine mature and juvenile wood that had been adjusted to a 50% pulp yield suggest differences between species and between types of wood (mature and juvenile) are less than the differences encountered as the result of cooking conditions.

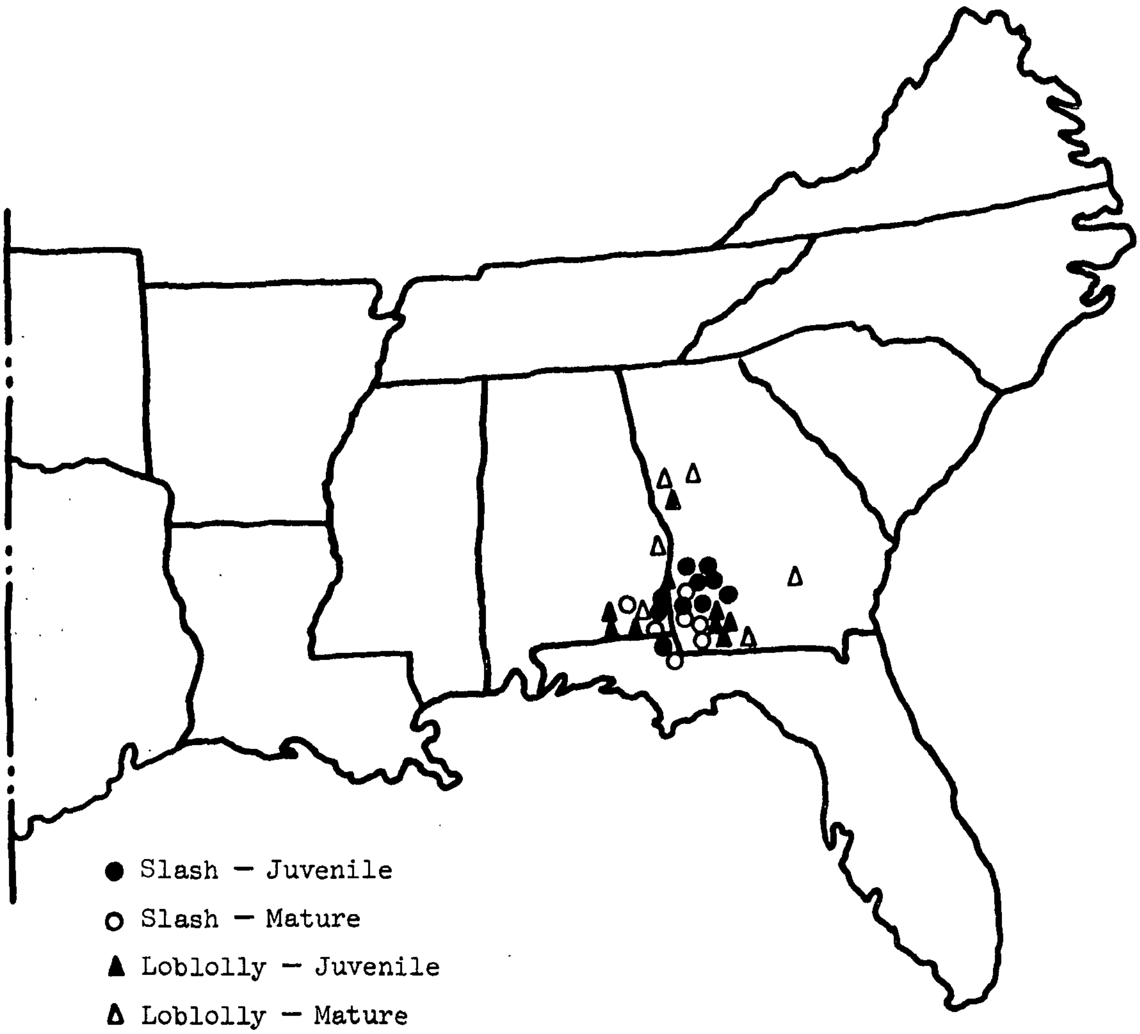


Figure 30. Sampling Areas of Great Northern Samples of Slash and Loblolly Pine Used in Pulping and Weight Factor Studies

The suggested weight factor of 1.55 (TAPPI Standard T 401 m-60) for most pulps prepared from species of southern yellow pine should be employed in fiber analysis work unless a complete history (i.e., species, class of wood, cooking conditions, etc.) of the pulp sample in question is known. When either pulp yield or Kappa number is known, it is possible to obtain adjusted weight factors through the use of linear regression procedures (see Fig. 14). Where greater accuracy in a particular analysis is required than the tolerances listed in the TAPPI Standards, it would be necessary to determine the relative weight factors for the actual pulps present in a sample furnish.

The weight factors determined for pulps prepared from several species of white oak were approximately the same as those obtained for similar pulps prepared from red oak. The factors for all pulps prepared from these species were in every instance, lower than the TAPPI suggested factor of 0.60 or 0.70 and reported as being used for these pulp species. The results of this investigation suggest that a weight factor of 0.45-0.50 would be more appropriate for pulps prepared from oak species. There was a wide variation in the geographic locations of the sample areas. The data obtained in this study would indicate that variations in wood density, which certainly must occur within trees, between trees and also in terms of site and geographic variability, are probably not significant and have little effect on the ultimate weight factor values that should be used.

PLANS

Plans for the program during the next six months include completion of weight factor determinations on northern and western softwood chemical pulp samples and also on chemical pulps prepared from other species of hardwood. The development of a set of relative weight factors for hardwood species based on "vessel counts" will also be made.

Future plans include the completion of weight factor determinations for all other high priority pulps submitted by members of the project.

ACKNOWLEDGMENTS

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GLOSSARY

Apotracheal parenchyma. Axial parenchyma typically independent of the pores or vessels. (Formerly known as metatracheal.)

Biseriate ray. Ray consisting of two rows of cells, as viewed in the tangential section.

Epidermis. The outer single layer of cells on an organ.

Epithelium. Excreting parenchymatous tissue surrounding the cavity of resin and gum canals.

Fusiform ray. Spindle-shaped ray, as viewed in a tangential section of wood, containing a transverse resin canal.

Paratracheal parenchyma. Parenchyma obviously associated with the vessels.

Parenchyma. Tissue consisting of short, relatively thin-walled cells, generally with simple pits; concerned primarily with storage and distribution of carbohydrates.

Ray. Ribbon-shaped strand of tissue extending in a radial direction.

Resin canal. An intercellular space, often bordered by secreting cells, containing resin.

SEM. Scanning electron microscope.

Tracheid. Fibrous lignified cell with bordered pits and imperforate ends; in coniferous wood, the tracheids are very long (up to 7+ mm.) and are equipped with large, prominent bordered pits on their radial walls; tracheids in hardwoods are shorter fibrous cells (seldom over 1.5 mm.), are as long as the vessel elements with which they are associated, and possess small bordered pits.

Tyloses. Saclike or cystlike structures that sometimes develop in a vessel and rarely in a fiber through the proliferation of the protoplast (living contents) of a parenchyma cell through a pit pair.

Tylosoids. Balloonlike structures in resin canals resembling tyloses in hardwoods.

Storied. Arranged in tiers or in echelon, as viewed on a tangential surface or in a tangential section.

Uniseriate. Arranged in a single row, series, or layer. Also said of a wood ray which is one cell wide in cross-section.

Vasicentric. Paratracheal.

Vessel. Composite, and hence articulated, tubelike structure found in porous wood (hardwoods), arising through the fusion of the cells in a longitudinal row through the partial or complete disappearance of the common walls.